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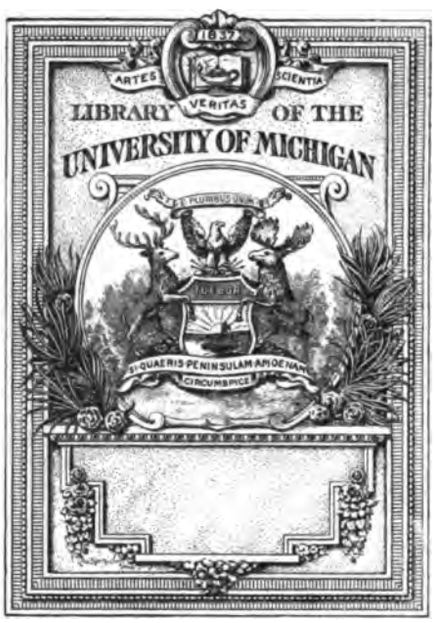
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—(26.)—

SEWAGE DISPOSAL (ROYAL COMMISSION).

Session

23 *January* 1901 —— 17 *August* 1901.

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1901.

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INTERIM REPORT

OF

THE COMMISSIONERS

APPOINTED IN 1898

TO INQUIRE AND REPORT WHAT METHODS OF

TREATING AND DISPOSING OF SEWAGE

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

Presented to both Houses of Parliament by Command of His Majesty.

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VICTORIA R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith : To Our Right Trusty and Right Well-beloved Cousin, Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath ; Our Trusty and Well-beloved Sir Richard Thorne Thorne, Knight Commander of Our Most Honourable Order of the Bath, Medical Officer of the Local Government Board ; Our Trusty and Well-beloved Constantine Phipps Carey, Esquire, Lieutenant-Colonel and Honorary Major-General on the Retired List of Our Army ; Our Trusty and Well-beloved Charles Philip Cotton, Esquire ; Our Trusty and Well-beloved Michael Foster, Esquire, Master of Arts, Professor of Physiology in Our University of Cambridge ; Our Trusty and Well-beloved Thomas Walter Harding, Esquire, Retired Lieutenant-Colonel of Our Auxiliary Forces, with Honorary Rank of Colonel ; Our Trusty and Well-beloved Thomas William Killick, Esquire ; Our Trusty and Well-beloved William Ramsay, Esquire, Professor of Chemistry, University College, London ; and Our Trusty and Well-beloved James Burn Russell, Esquire, Doctor of Medicine, Master of Surgery : Greeting !

Whereas We have deemed it expedient that a Commission should forthwith issue to inquire and report :

1. (1) What method or methods of treating and disposing of sewage (including any liquid from any factory, or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of the public health, and for the economical and efficient discharge of the duties of local authorities ; and

   (2) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined ; and

2. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage ;

Now know ye, that We, reposing great trust and confidence in your knowledge and ability, have authorised and appointed, and do by these Presents authorise and appoint, you, the said Walter Stafford, Earl of Iddesleigh, Sir Richard Thorne Thorne, Constantine Phipps Carey, Charles Philip Cotton, Michael Foster, Thomas Walter Harding, Thomas William Killick, William Ramsay, and James Burn Russell to be Our Commissioners for the purposes of the said Inquiry.

And, for the better effecting the purposes of this, Our Commission, We do by these Presents give and grant unto you, or any three or more of you,

full power to call before you such persons as you shall judge likely to afford you any information upon the subject of this Our Commission; and also to call for, have access to, and examine, all such books, documents, registers, and records as may afford you the fullest information on the subject, and to inquire of and concerning the premises by all other lawful ways and means whatsoever.

And We do by these Presents authorise and empower you, or any three or more of you, to visit and personally inspect such places as you may deem it expedient so to inspect for the more effectual carrying out of the purposes aforesaid.

And We do further by these Presents will and ordain that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, and of every matter and thing therein contained, although the same be not continued from time to time by adjournment.

And We do further ordain that you, or any three or more of you, have liberty to report your proceedings under this Our Commission from time to time, if you shall judge it expedient so to do.

And Our further Will and Pleasure is that you do, with as little delay as possible, report to Us under your hands and seals, or under the hands and seals of any three or more of you, your opinion upon the matters herein submitted for your consideration.

And for the purpose of aiding you in such matters, We hereby appoint Our Trusty and Well-beloved Frederick James Willis, Esquire, to be Secretary to this Our Commission.

Given at Our Court at Saint James's, the Seventh day of May, One thousand eight hundred and ninety-eight, in the Sixty-first Year of Our Reign.

By Her Majesty's Command,

(Signed) M. W. Ridley.

William Henry Power, Esq., F.R.S.,
To be a Member of the Royal Commission on Sewage Disposal.

VICTORIA, R.

Victoria, by the Grace of God, of the United Kingdom of Great Britain and Ireland, Queen, Defender of the Faith: To Our Right Trusty and Well-beloved William Henry Power, Esquire, Fellow of the Royal Society, Medical Officer of the Local Government Board: Greeting!

Whereas We did, by Warrant under Our Royal Sign Manual, bearing date the Seventh day of May, One thousand eight hundred and ninety-eight, appoint Our Right Trusty and Right Well-beloved cousin Walter Stafford, Earl of Iddesleigh, Companion of Our Most Honourable Order of the Bath, together with the several Gentlemen therein mentioned, or any three or more of them, to inquire into the treatment and disposal of sewage.

And Whereas One of the Commissioners so appointed, namely, Sir Richard Thorne Thorne, has since deceased.

Now know Ye, that We, reposing great confidence in you, do, by these presents, appoint you, the said William Henry Power, to be one of Our Commissioners for the purpose aforesaid, in the room of the said Sir Richard Thorne Thorne, deceased, in addition to, and together with, the other Commissioners whom we have already appointed.

Given at our Court, at Saint James's, the Seventh day of February, One thousand nine hundred, in the Sixty-third Year of Our Reign.

By Her Majesty's Command,

(Signed) M. W. RIDLEY.

Whitehall, March 18th, 1901.

THE KING has been pleased to issue a Commission, under His Majesty's Royal Sign Manual, to the following effect:—

EDWARD, R.

Edward the Seventh, by the Grace of God, of the United Kingdom of Great Britain and Ireland King, Defender of the Faith, to all to whom these Presents shall come, Greeting!

Whereas it pleased Her late Majesty from time to time to issue Royal Commissions of Inquiry for various purposes therein specified:

And Whereas in the case of certain of these Commissions, namely, those known as—

The Historical Manuscripts Commission;
The Horse Breeding Commission;
The Local Taxation Commission;
The Port of London Commission;
The Salmon Fisheries Commission; and
The Sewage Disposal Commission;

the Commissioners appointed by Her late Majesty, or such of them as were then acting as Commissioners, were, at the late demise of the Crown, still engaged upon the business entrusted to them:

And whereas We deem it expedient that the said Commissioners should continue their labours in connection with the said inquiries notwithstanding the late demise of the Crown:

Now know Ye, that We, reposing great trust and confidence in the zeal, discretion, and ability of the present members of each of the said Commissions, do by these Presents authorize them to continue their labours, and do hereby in every essential particular ratify and confirm the terms of the said several Commissions.

And We do further ordain that the said Commissioners do report to Us under their hands and seals, or under the hands and seals of such of their number as may be specified in the said Commissions respectively, their opinion upon the matters presented for their consideration; and that any proceedings which they or any of them may have taken under and in pursuance of the said Commissions since the late demise of the Crown, and before the issue of these Presents shall be deemed and adjudged to have been taken under and in virtue of this Our Commission.

Given at Our Court at Saint James's, the fourth day of March, One thousand nine hundred and one, in the First Year of Our Reign.

By His Majesty's Command,

(Signed) CHAS. T. RITCHIE.

INTERIM REPORT.

TO THE KING'S MOST EXCELLENT MAJESTY.

MAY IT PLEASE YOUR MAJESTY,

We, the Commissioners appointed to inquire and report :—

I. (1) What method or methods of treating and disposing of sewage (including any liquid from any factory or manufacturing process) may properly be adopted, consistently with due regard for the requirements of the existing law, for the protection of public health, and for the economical and efficient discharge of the duties of Local Authorities; and

(2) If more than one method may be so adopted, by what rules, in relation to the nature or volume of sewage, or the population to be served, or other varying circumstances or requirements, should the particular method of treatment and disposal to be adopted be determined; and

II. To make any recommendations which may be deemed desirable with reference to the treatment and disposal of sewage.

Humbly report, as follows :—

PRELIMINARY.

1. We have examined a large number of witnesses, and visited many sewage works of various kinds. We have also instituted through our own officers a number of necessary scientific investigations.

2. Many of these investigations are still in progress, and considerable time must necessarily be taken by the work which still remains to be done, and especially by such work as is needed before the second part of the Terms of Reference can be adequately dealt with.

3. We have, however, arrived at conclusions on three questions which appear, for reasons hereafter given, to be of urgent importance and we have therefore deemed it desirable to make a preliminary report and to publish the evidence already taken.

The three questions are :—

(1) Are some sorts of land unsuitable for the purification of sewage.

(2) Is it practicable uniformly to produce by artificial processes alone an effluent which shall not putrefy, and so create a nuisance in the stream into which it is discharged.

(3) What means should be adopted for securing the better protection of our rivers.

Conclusions of previous Commissions.

4. Mr. Alfred Douglas Adrian, C.B., who, as Assistant Secretary of the Local Government Board, had charge for some years of the department concerned with questions of sewerage and sewage disposal, was the first witness whom we examined. His evidence contains a most valuable historical statement of the subject of sewage disposal, of the law on the subject, and of the practice of the Local Government Board in regard to this matter.

5. The first Sewage Commission was appointed in the year 1857. In 1865, as a result of labours extending over eight years, they reported that :— Adrian, 35.

"The right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided." Adrian, 52.

Adrian, 56. 6. In 1868, a further Commission was appointed to inquire into the best means of preventing the pollution of rivers. They made several reports, the fifth and last being made in 1874.

Adrian, 61. The opinion of this Commission on the comparative merits of the three classes of processes for the treatment of sewage, viz.:—chemical precipitation, intermittent filtration, and broad irrigation, may be stated thus:—(1) All these processes are to a great extent successful in removing polluting organic matter in suspension. But intermittent filtration is best, broad irrigation ranks next, and the chemical precipitation processes are less efficient. (2) But for removing organic matters in solution the processes of downward intermittent filtration and broad irrigation are greatly superior to upward filtration and chemical processes.

7. The last Commission was appointed in 1882. They were directed to inquire into and report upon the system under which sewage was discharged into the Thames
Adrian, 71. by the Metropolitan Board of Works, whether any evil effects resulted therefrom, and, if so, what measures could be applied for remedying or preventing the same.

In November 1884 they issued their final Report. They found that evils did exist "imperatively demanding a prompt remedy," and that by chemical precipitation a certain part of the organic matter of the sewage would be removed. They reported,
Adrian, 74. however, "that the liquid so separated would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a permanent measure. It would require further purification, and this, according to the present state of knowledge can only be done effectually by its application to land."

Practice of Local Government Board.

Adrian, 107. 8. Since the publication of the last-mentioned Report it has been the practice of the Local Government Board to require, save in exceptional cases, that "any scheme of sewage disposal, for which money is to be borrowed with their sanction, should provide for the application of the sewage or effluent to an adequate area of suitable land before its discharge into a stream." There can be no doubt, in our opinion, that the Local Government Board were bound, under the circumstances, to insist upon such a rule.

Reasons for Reconsidering Position.

Tatton, 261, 284, 402–4, 6632. Naylor, 931. Barwise, 4028. Maclean Wilson, 6138–9. 9. It is now contended that in many cases, especially in the great centres of manufacturing industry, the land available is either of unsuitable quality, is available in quite inadequate area for effective filtration through the soil, or is obtainable only at a prohibitive cost, and it is suggested that sewage purification may, in such cases, be carried out on comparatively small areas artificially prepared. During recent years a variety of artificial processes, differing from those which were considered by the earlier Commissions, have been elaborated for treating sewage, and it is urged that satisfactory effluents can be obtained by such artificial processes.

Scope of Work of this Commission.

10. Having regard to the definite findings of previous Commissions, to the consequent practice of the Local Government Board in insisting on the provision of land for the purification of sewage, and to the fact that the artificial processes are still only in the experimental stage and, as might be expected therefore, the evidence in regard to them is inconclusive on many points, it has appeared to us essential to subject the artificial processes to sustained examination, and also carefully to test the contention that in certain cases it is not practicable to purify sewage by land treatment.

11. At the time of the investigations of the earlier Commissions, the science of bacteriology was in its infancy, and these Commissions confined themselves almost entirely to a chemical examination of sewage effluents. Since the dates of those Commissions a large amount of exact knowledge has been gained concerning the part played by bacteria in various processes of nature and operations of man, and it became our duty to study the various questions connected with sewage disposal, not

only from a chemical but from a bacteriological point of view as well. This has largely increased our labours, but we trust will also largely increase their usefulness. We have had to initiate and carry out various bacteriological investigations, and, in particular, finding that the work done by earlier Commissions in regard to land treatment was not complete enough for our purposes, we have thought it necessary to include in our work a systematic investigation, bacteriological as well as chemical, of the treatment of sewage on land of various kinds. This investigation is on the point of completion.

Officers appointed.

12. For the purpose of our own work we appointed the following officers :—

Professor Boyce, Bacteriologist.
Dr. Houston, Bacteriologist.
Dr. McGowan, Chemist.
Mr. Colin Frye, Chemist.
Mr. G. B. Kershaw, Engineer.

Question I. :—Are some sorts of Land Unsuitable for the Purification of Sewage.

Conclusions as to certain sorts of land.

13. As regards the allegations that certain sorts of land are so unsuitable as to render them practically useless for the purification of sewage, we have received evidence from a number of witnesses who have had much experience of sewage treatment. Almost without exception their testimony is to the effect that peat and stiff clay lands are unsuitable for the purification of sewage.

14. Our own officers have made a large number of analyses of effluents from well-managed farms with different classes of soil, and their results support this general opinion.

CONCLUSION 1.

15. We doubt if any land is entirely useless, but in the case of stiff clay and peat lands the power to purify sewage seems to depend on the depth of the top soil.

There are, of course, numerous gradations in the depths of top soil which are met with in nature, and it is not easy to draw the line between lands which contain a sufficient depth to justify their use, and lands which do not.

We are, however, forced to conclude that peat and stiff clay lands are generally unsuitable for the purification of sewage, that their use for this purpose is always attended with difficulty, and that where the depth of top soil is very small, say six inches or less, the area of such lands which would be required for efficient purification would in certain cases be so great as to render land treatment impracticable.

Further information with regard to this point will be available when our investigation of Land Treatment is completed.

Question II. :—Is it practicable uniformly to Produce by Artificial Processes alone an Effluent which shall not Putrefy and so Create a Nuisance in the Stream into which it is Discharged.

Purification obtainable by artificial processes.

16. The following general classification will serve to show the nature of the artificial processes to which we refer :—

Closed septic tank and contact beds.
Open septic tank and contact beds.
*Chemical treatment, subsidence tanks, and contact beds.
Subsidence tanks and contact beds.
Contact beds alone.
Closed septic tank followed by continuous filtration.
Open septic tank followed by continuous filtration.
Chemical treatment, subsidence tanks, and continuous filtration.
Subsidence tanks followed by continuous filtration.
Continuous filtration alone.

* The expression "subsidence tanks" is intended to denote tanks which are used in such way that little or no "septic" action is produced.

17. Many valuable experiments on artificial treatment have been made by a number of local authorities, and in particular the Corporations of Leeds and Manchester have subjected certain processes to sustained observation. In this way much reliable information has been obtained.

18. We are not, however, in a position to express an opinion upon the relative merits of the several artificial processes, nor can we at present make a complete comparison between land treatment and artificial treatment of sewage, or state how far purification of sewage can be uniformly effected by one or another artificial process, and at what cost as compared with land treatment.

The character of the sewage of different towns varies to a considerable extent, especially in respect to the amount and nature of the trade refuse mixed with the domestic sewage, but also in respect to domestic sewage itself; and a method applicable to one sewage might not be applicable to another. The problems involved in the matter are so many and so varied that only investigation, and, we may add, experience of a prolonged and varied character, will suffice to solve them.

CONCLUSION 2.

19. After carefully considering, however, the whole of the evidence, together with the results of our own work, we are satisfied that it is practicable to produce by artificial processes alone either from sewage, or from certain mixtures of sewage and trade refuse such, for example, as are met with at Leeds and Manchester, effluents which will not putrefy, which would be classed as good according to ordinary chemical standards, and which might be discharged into a stream without fear of creating a nuisance.

We think, therefore, that there are cases in which the Local Government Board would be justified in modifying, under proper safeguards, the present rule as regards the application of sewage to land.

No general rule as to what these safeguards should be can be laid down at present, and indeed it will, probably, always be necessary that each case should be considered on its own merits.

Bacteriological Qualities of Effluents. Sewage Effluents in Relation to Disease.

20. As we have already said sewage effluents must, in accordance with present knowledge, be judged not only from a chemical but also from a bacteriological point of view. In order to safeguard public health, it is, in certain cases at any rate, not enough to know the chemical features of an effluent and to ascertain that it will not putrefy of itself, we must know the bacteriological features as well.

Thomson, 1392. Adeney, 2445–6. Marshall Ward, 2653–5; 2727–2748. Woodhead, 2988. Frankland, 3043–8. Roscoe, 3653–5; 3662. Barwise, 4041. Rideal, 4406. Thresh, 8956–7.

21. Several witnesses have referred to the danger of allowing pathogenic organisms to enter streams which are used for drinking purposes, and our own officers are carrying out careful prolonged investigations on this matter.

We are impressed with the great importance of the bacteriological questions which have arisen in the course of our Inquiry, but we do not, at present, feel justified in putting forward any conclusions concerning them.

We may, however, even at this stage point out, that as a result of a large number of examinations of effluents from sewage farms and from artificial processes we find that while in the case of effluents from land of a kind suitable for the purification of sewage there are fewer micro-organisms than in the effluents from most artificial processes, yet both classes of effluents usually contain large numbers of organisms, many of which appear to be of intestinal derivation, and some of which are of a kind liable, under certain circumstances at least, to give rise to disease.

We are of opinion, therefore, that such effluents must be regarded as potentially dangerous, and we are considering whether means are available and practicable for eliminating or destroying such organisms, or, at least, those giving rise to infectious diseases.

QUESTION III.:—WHAT MEANS SHOULD BE ADOPTED FOR SECURING THE BETTER PROTECTION OF OUR RIVERS.

22. From the evidence which we have received, from our own observation, and from information collected for us by the Local Government Board for Scotland, we are satisfied that the Rivers Pollution Prevention Act, 1876, has not resulted in the general purification of our rivers. Protection of rivers. Curphey, 1822. Frankland, 3010.

23. This is due largely to the reluctance of the authorities to put the Act in force, but partly also to the difficulty which a sanitary authority experiences in proving that the pollution within its district comes from the district against which, or the person against whom, action is taken. An authority wishing uniformly to enforce the Act in its own district has no security that the authorities above and below it on the stream will do the same, and it is therefore naturally disinclined to take action. Tatton, 254. Curphey 1808; 1825–6. Roscoe, 3768.

24. The Local Government Act, 1888, Section 14 (1) and the Local Government (Scotland) Act, 1889, Section 55 (1), give to County Councils of England and Wales and Scotland "power in addition to any other authority to enforce the provisions of the Rivers Pollution Prevention Act, 1876, in relation to so much of any stream as is situate within or passes through or by any part of their county."

25. This concurrent power of the County Council does away with the difficulty of proving pollution within a district from a source within the area of the county, though outside the district, and it should insure equal and fair treatment for all authorities and persons within the county. Several county councils are putting the Act into operation and are making good progress.

26. Section 14 (3) of the Act of 1888 provides that "The Local Government Board by Provisional Order made on the application of the council of any of the counties concerned may constitute a Joint Committee or other body representing all the administrative counties through or by which a river, or any specified portion of a river, or any tributary thereof passes, and may confer on such committee or body all the powers of a sanitary authority under the Rivers Pollution Prevention Act, 1876, or such of them as may be specified in the Order," and similar powers are conferred on the Secretary for Scotland by Section 55 (3) of the Local Government (Scotland) Act, 1889.

27. Under the Local Government Act, 1888, the Mersey and Irwell Joint Committee, the Ribble Joint Committee, and the West Riding Rivers Board have been constituted. The evidence shows that these bodies have done much useful work in enforcing the treatment of sewage and trade refuse, and that it is of considerable importance to have for each watershed a single authority. Tatton, 256 Scudder, 497; 6149. Naylor, 845. Maclean Wilson, 1175–6 Roscoe, 3554. Hibbert, 7885–7.

The advantages a county has in enforcing the Rivers Pollution Prevention Act, 1876, are also possessed by a Joint Committee of more than one county, and are increased in proportion to the wider area.

28. But those councils or committees of more than one county who are enforcing the Act feel the injustice of compelling their authorities and manufacturers to purify their effluents, whilst in other parts of the country and over wide areas little or nothing is being done. Tatton, 273.

29. Previous Commissions have referred to the necessity of setting up watershed boards, and otherwise strengthening the machinery for the protection of our rivers, as the following extracts will show :—

EXTRACTS from Second Report of the Commission appointed in 1857 to inquire into the best mode of distributing the sewage of towns.

"We have now to urge, as the first and all-important step towards securing this object and the "permament improvement and protection of the rivers of the country, that a general local jurisdiction and "conservancy be created throughout the kingdom, with adequate powers and proper guarantees for their "due administration." Page 9.

* * * * * *

"The abuses and nuisances which have now grown up with the growth of towns and manufactures urgently demand some available law for the conservancy of rivers, from their sources to their outfalls."

* * * * * *

Page 40. "Having now fully stated our conclusions as to the means of disposing of the sewage of towns, and "shown that the remedies for the evils which are experienced, although various, are both practicable and "economical, we beg to repeat our conviction that the only security for a general and continued employment "of such means will be the establishment of responsible conservancies throughout the country, armed with "adequate powers."

EXTRACTS from First Report of the Commissioners appointed in 1865 to inquire into the best means of preventing the Pollution of Rivers.

Page 32. "We also humbly submit the following Recommendations to Your Majesty :—

"That the whole river be placed under the superintendence of one governing body."

"That it be made incumbent upon the Conservators to see to the enforcement of the above prohibitions "against pollution of the river. . . ."

EXTRACTS from Third Report of the Commissioners appointed in 1865 to inquire into the best means of preventing the Pollution of Rivers.

Page 53. "Where manufactures have been established and a large resident population has grown up as before "stated, the greatest amount of pollution takes place, the area of country over which such form of nuisance "is spread having no defined boundary other than the dividing ridges of such watershed and the shores of "the sea. In order to prevent the Pollution and legally control the Management of rivers, their basins or "watersheds must be placed under supervision, irrespective of any arbitrary divisions of County, Parish, "Township, Parliamentary, Municipal, or Local Government Act boundaries; or, indeed, of any artificially "established division. Running waters flow on from their source to the sea, and if the upland waters are "polluted by town sewage and by refuse discharged from manufactures, as in the West Riding of Yorkshire, "the entire length of a river is necessarily polluted, and will require to be Conserved or protected."

Page 54. "One conclusion, therefore, forces itself upon anyone who honestly deliberates upon the existing state "of things in regard to the rivers we have visited with a view to its permanent improvement. A stronger "power than has hitherto been available must be brought to bear if the present abuse and pollution of "streams is to be arrested, and Government supervision and inspection must enforce and strengthen the "action of local authorities."

EXTRACT from First Report of the Commissioners appointed in 1868 to inquire into the best means of Preventing the Pollution of Rivers.

Separate Conclusions and Recommendations by Major-General Sir William Denison, K.C.B., Chairman.

Page 132. "The evidence we have had of the total disregard of mere legal enactments which tend to fetter the "actions of masses of people, of the constant evasions of obligations imposed by law, of the inefficiency of the "law, even when means have been found to bring it into action, to enforce the adoption of any special "remedy for the evils complained of, has satisfied me that it will be necessary to call into action an authority "superior to all those local municipalities, embracing in its scope the whole area of the watershed subdivided "among these bodies, and to confer upon such authority powers differing both in kind and degree from that "exercised by ordinary municipalities or conservancies."

EXTRACT from Third Report of the Commissioners appointed in 1868 to inquire into the best means of Preventing the Pollution of Rivers.

"RECOMMENDATIONS."

Page 56. "3. That all rivers and streams in England be placed under the superintendence of a central authority "or board, to be composed of not more than three persons, who shall be duly qualified to deal with all questions "connected with the pollution of water and with water supply.

"4. That it be the duty of this board to see that all enactments relating to the use or abuse of running "water be duly enforced; and that for this purpose power be given to it to inspect manufactories; reservoirs, "sewerage, and other similar works; and to cause to be constructed, at the expense of the owners of the "same, whether corporate or private, any necessary purifying apparatus, in case the said owners neglect or "refuse to provide such apparatus for themselves."

CONCLUSION 3.

30. We consider it of the utmost importance that the simplest possible means should be provided for adequately protecting all our rivers, and we are further of opinion that it will be desirable, probably for some time to come, that scientific experiments should be carried on in order to ascertain all the real dangers of pollution, against which they should be protected.

In the present state of knowledge, and especially of bacteriology, it is difficult to estimate these dangers with any accuracy, and it seems quite possible that they should be either exaggerated or undervalued according to the predisposition of those who have to deal with them. An authority, guided by medical considerations, might not unnaturally be inclined to insist on a degree of purity which may ultimately prove in certain cases to be uncalled for, while another authority, with its mind fixed upon economy, might shrink from taking essential precautions.

31. It is, perhaps, scarcely for us to say what arrangements should be made, but we are of opinion that the general protection of our rivers is a matter of such grave concern as to demand the creation of a separate commission, or a new department of the Local Government Board, which shall be a Supreme Rivers Authority, dealing with matters relating to rivers and their purification, and which, when appeal is made to them, shall have power to take action in cases where the local authorities have failed to do so.

32. We cannot conclude this Report without referring to the very serious loss which we sustained by the death of Sir Richard Thorne Thorne at a comparatively early stage of our Inquiry. He was a most active member of the Commission, and his advice and help were invaluable.

(Signed) IDDESLEIGH.
C. PHIPPS CAREY.
CHARLES P. COTTON.
M. FOSTER.
T. WALTER HARDING.
T. W. KILLICK.
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F. J. Willis, Secretary,
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AT 16, VICTORIA STREET, WESTMINSTER, S.W.

FIRST DAY.

Wednesday, 22nd June, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary*.

Mr. ALFRED DOUGLAS ADRIAN, C.B., Assistant Secretary to the Local Government Board, called; and Examined.

Mr. A. D. Adrian, C.B. — 22 June 1898.

1. (*Chairman.*) Mr. Adrian, I think you are an Assistant Secretary to the Local Government Board?—Yes, my Lord.

2. And in that capacity you have had charge for some years of the department concerned with questions of sewerage and sewage disposal?—Yes.

3. Now you have been asked to give evidence with respect to the law relating to sewage disposal, so far as regards England and Wales, and with respect to any point arising out of the practice of the Board that may be of interest to the Commission?—Quite so.

4. Would you mind, at the outset, explaining what method you propose to adopt in the arrangement of your evidence?—I propose, in the first instance, to give, in the form of a chronological summary, an account of the origin and growth of the general Statute law. I propose to follow this summary by a statement, with appropriate commentary, of the effect of the general Statute law as it now exists. Lastly, I propose to make a few observations in illustration of the past and present practice of the Department when dealing with schemes of sewage disposal.

5. Have you anything to say by way of preface to your account of the origin and growth of the law?—I think it may be said of the law relating to sewage disposal, as embodied in the general Statutes now in force, that one of its most striking features is the composite character of its provisions. This, of course, is the necessary consequence of the circumstances in which the law has been gradually built up. For, in dealing with this matter, the Legislature and the Government Departments which have, from time to time, been concerned with its administration have never been in the position of having, as it were, a clean sheet upon which to record a precise code of rules. At the outset, the varying practice of different communities almost necessarily imparted to the beginnings of legislation a more or less tentative character. And, in later stages, the successive contributions to the Statute law have taken the form of grouping about the original nucleus, rules devised to facilitate some special purpose to which the prevailing opinion of the time attached a peculiar importance. It seems to me, therefore, that to a proper appreciation of the law, as it now stands, a preliminary survey of the circumstances of its growth is absolutely essential; and such a survey is materially helped by a summary of the conclusions which, as the outcome of official or parliamentary investigations, or of the labours of previous Royal Commissions, may be regarded as influencing the legislation of the time. On such a survey we find, I think, that, taking the half century during which the Statute law on the subject of sewage disposal has been in process of evolution, there are three distinct periods, each of which is marked by a dominant opinion as to the essentials of a proper system of sewage disposal.

6. You have spoken of three periods for the purposes of your survey. Now the first period—what is that?—The first period comprises the years from 1842 to 1857. During that time the conclusions to be drawn from official and parliamentary publications seem to me to be these: That it was of the first importance to secure the prompt removal of sewage from the neighbourhood of dwellings: That the use of a river outfall was preferable to retention of sewage near dwellings: That, in consequence of doubts as to the effect upon the public health of the irrigation of large surfaces with liquid sewage, the best system of disposal was by underground pipes for subsequent distribution by hose or jets.

7. What are your remarks upon the second period?—In the second period I should group the years 1858 to 1870.

Mr. A. D. Adrian, C.B.

22 June 1898.

This period yields as the published results of the investigations which it covers: (1) The abandonment of the notion of possible injury to health as a consequence of the irrigation of land by sewage; and (2) the growth of the belief in the ideal system of sewage disposal as being that which should aim at its profitable utilisation by direct application to land, and should thus facilitate the protection of rivers from contamination.

8. And the third period?—To the third period, that is, to the years from 1870 to the present time, is to be attributed, as a dominant idea which finds expression in official and parliamentary publications and in legislation, the opinion that the prevention of the pollution of streams is an indispensable requisite of every system of sewage disposal which can lay claim to efficiency.

9. Now would you mind stating in detail what you have noted as important in relation to the first of these periods?—Of the facts which I have noted, the first in chronological order may be said to be the application of sewage by open irrigation to the Craigentinny Meadows at Edinburgh. The origin of this system is generally attributed to the close of the 18th century. In 1842 an official observer (Mr.—afterwards Sir—E. Chadwick) in his report to the Poor Law Commissioners on the sanitary condition of the labouring population of Great Britain described the process at some length. I mention Mr. Chadwick in this connection, because it is stated in the evidence taken by a Commission appointed in 1843 to inquire into the state of large towns and populous districts that irrigation had been practised from the beginning of the present century at Ashburton and elsewhere in Devon, but that until Mr. Chadwick drew attention to the subject little had been said or thought of it. But whether because Mr. Chadwick was influenced by the opinion of his fellow observer, Dr. Arnott, who regarded the process as unfitted for the vicinity of a town, or because in view of legal proceedings then pending at the instance of the Government for the protection of Holyrood Palace against injury to health, it was necessary to write cautiously, Mr. Chadwick's opinion was by no means favourable to the practice. But, at the same time, he pointed out that, if the contents of the cesspools were carried by adequate supplies of water in drains from the houses into covered sewers, and thence in covered instead of open sewers to the lands at proper distances, where the contents might be distributed as manure by irrigation, this, according to the authorities whom he had consulted, would have been the best method then apparently practicable.

10. Have you any remarks to make upon the mention of sewers in the recommendation you have just summarised?—Yes. There is the fact that the sewers of the time at which Mr. Chadwick wrote were not generally designed to effect the purpose that he had in view in his sketch of an improved process. At the beginning of the century sewers were intended for surface water only. Water closets were introduced about 1810. They discharged into cesspools; but as the use of the closets extended, an overflow into the street sewers became inevitable. Now in 1842 the sewers which were generally regarded as the best examples of such works, viz., the Metropolitan Sewers, were thus described by Mr. Chadwick: "The general defect of these works is that they are so constructed as to accumulate deposits within them: that the accumulations remain for years, and are at last only removed at a great expense and in an offensive manner by hand labour and cartage." For cleansing purposes the streets were opened. Men descended, scooped up the deposit into pails, which were raised by a windlass to the surface, and laid there until the carts came.

11. Have you any information as to the condition of things elsewhere besides the Metropolitan Sewers?—Yes. The Commission of 1843 records facts which clearly show that the condition of things elsewhere was worse. The sewers in use were such as had been constructed primarily for surface water by Commissions of Sewers, acting for about 80 districts outside the Metropolis (according to the estimate of 1843) under the Statute of the 23 Henry VIII. c. 5. Or the sewers were in fact highway drains. As to the highway drains very serious nuisance was reported. The General Highway Act of 1835 empowered, but did not compel, highway surveyors to cleanse these drains. And the powers of an earlier Act (13 George III. c. 78, s. 8) which required cleansing by adjoining occupiers had been repealed. Consequently the Commissioners of 1843 say: "The exhalations and offensive effluvia arising from the non-cleansing of such drains producing fevers and other diseases" were found to "add to the miseries of the poorer inhabitants, and to the expenses both of the parish and individuals."

12. Now, the preliminary facts to which you have drawn our attention are, first, the existence in 1842 of at least one example of irrigation of some antiquity, and, secondly, the defects of the sewers of the period. Is there any other point?—There is a third point to which I wish to allude, and that is Mr. Chadwick's opinion upon the use of streams as sewage outfalls. While he regarded such use of streams as a far less evil than the retention of filth among large masses of the population, he considered that an improved water carriage system might convey refuse cheaply and innoxiously to any distance out of towns, and in the best form for productive use, and that the loss and injury by the pollution of natural streams might thus be avoided.

13. You are now approaching the legislation of this first period. What is your earliest example of this?—Taking Mr. Chadwick's report as showing, as it were, the high water mark of the opinion of the time upon sewerage and sewage disposal, one is not surprised to find, in the first example of general legislation with regard to these subjects, evidence that the accepted standard of requirements fell short of the official ideal. The legislation to which I refer is that comprised in the Towns Improvement Clauses Act, 1847. This was one of a series of Acts passed with the view of avoiding the necessity of repeating provisions usually contained in Local Acts, and for ensuring greater uniformity in these provisions. The Act may be regarded, therefore, as exhibiting a revised version of what would be found at the time in Local Acts for towns improvement.

14. Would you give us any details of what is noteworthy in that Act?—The Act recognises two methods of sewage disposal. First, there was the method of getting rid of sewage without any profitable return. The local authority for this purpose might cause their sewers to communicate with and empty themselves into the sea or any public river (sec. 24). Secondly, there was the method of profitable disposal. The local authority might cause the refuse from their sewers to be conveyed by a proper channel to the most convenient site for its collection and sale for agricultural or other purposes, as might be deemed most expedient, but so that the same should in no case become a nuisance (sec. 24).

15. (*Mr. Killick.*) The same section?—Yes, the same section.

16. (*Chairman.*) Have you any point to make in connection with the provisions of the Act as regards sewage disposal without profitable results?—As regards the first of these methods, viz.: that by a sea or river outfall, it is to be observed that the expression "public river" did not restrict the outfall to tidal waters.

17. It did not?—It did not. The expression may be explained by a reference to Lord Hale's treatise (De Jure Maris, pt. I., cl. 3), as meaning a river which is *publici juris*, and a common highway for man and goods—a navigable stream which may be fresh or salt, and may flow or reflow or not.

18. As to the second mode of disposal, have you any observations on that?—With respect to the second method of disposal, it is to be noted that there are several provisions in the Act which point to the conception of a sewer as a possible sewer of deposit, and to such a destination of its contents as would be consistent with that conception. It may have been considered that provisions of this kind would certainly be needed, if not for the sewers constructed by the local authority, at least for the sewers which became vested in them by virtue of section 22. Accordingly, the local authority were required to make such reservoirs, sluices, engines, and other works as should be necessary for cleansing their sewers (section 24). They might employ scavengers or contract for scavenging, including the cleansing and emptying of sewers (section 95). Filth collected from the sewers was to be the property of the local authority, who could sell and dispose of it as they thought proper (section 90). They could appoint places for its deposit (section 95), and could themselves provide such places in the shape of buildings or lands (section 91).

19. And, lastly, as regards sewage disposal by sea or river outfalls, are there any incidental provisions in the Act of 1847 to be mentioned?—It may be noted that in the system which the Towns Improvement Clauses Act, 1847, recognised as permissible, the sea or a public river was regarded as an appropriate outfall for house drainage, by way of alternative to connection with a sewer or cesspool (sections 35 and 36); and the local authority, where the sea or river was within 100 feet of the house or building,

were required, in certain circumstances, to construct the communicating drain (sections 35 and 36).

20. You have dealt with the legislation of 1847; have you anything to say with regard to the next year—1848?—In 1848 the first Public Health Act was passed. This Statute was, as the preamble shows, intended to provide, under the supervision of a temporary body—the General Board of Health—a scheme of local management and control for the improvement of the sanitary condition of towns and populous places, with the exception of certain Metropolitan areas. This Act also contained provisions which recognise the alternatives of non-profitable and profitable methods of sewage disposal.

21. And as regards the non-profitable disposal, what are the chief points to be noted in the Act?—It is to be observed that the express mention of the sea or a public river as an appropriate outfall for the sewers of a local authority is not repeated.

22. Not repeated?—Not repeated. By section 46 the local authority were to cause all or any of the sewers vested in them "to communicate with and be emptied into such places as may be fit and necessary." Some restriction was put upon the selection of a watercourse as a place of outfall by the provisions of section 145. Under that section nothing in the Act was to be construed to authorise the local authority, without previous consent in writing, to use, injure, or interfere with any watercourse or stream in which the owners of certain property or the proprietors of canals or navigations might be interested.

23. What were the provisions of the Act with respect to the profitable disposal of sewage?—As to profitable methods of sewage disposal, the Act of 1848 did not in express terms mark any distinct advance upon the legislation of the previous year. By section 46 the local authority might cause the sewage and refuse from their sewers to be collected for sale for any purpose whatsoever, but so as not to create a nuisance. For the purpose of clearing, cleansing, and emptying the sewers, they might construct reservoirs, sluices, engines, and other works. They might also under section 56 provide fit buildings and places for the deposit of sewage collected by them, and sewage so collected was to be vested in and sold and disposed of by them. House drains might still in certain circumstances have direct communication with the sea (section 49). But the express mention of a public river as a possible outfall for these drains was not repeated.

24. Then dealing still with the first of the three periods, in order of date, what is the next fact to which attention should be drawn?—On the 6th of January, 1854, the first General Board of Health, whose term of office was then drawing to a close, presented a report upon their administration of the Public Health Act, 1848. Concerning sewage disposal, there is an appendix of "Conclusions obtained on application of sewer water and town manures to agricultural production."

25. Can you tell us what, briefly, is the effect of those conclusions of the General Board of Health?—The General Board of Health were of opinion that it was far less injurious to the public health to have the refuse of towns in water in the next river than underneath or amidst dwellings. Also they considered that there had been no satisfactory trials on a large scale of chemical substances as deodorisers or disinfectants. Two conclusions embodying the sanitary results of the investigations of the General Board of Health may perhaps be quoted *in extenso*. The first was: "That the application of manures to the surface "of land by means of irrigation is less injurious than the "application of the same quantities of manure in the "common method as top-dressing; but that the common "practice of irrigation with plain water is often productive "of ague, and, when conducted near dwellings, is other-"wise injurious to health; and that the creation of largely "extended evaporating surfaces from sewer water near "towns (though still far less injurious than the retention "of refuse and its decomposition within towns and under-"neath habitations) ought to be avoided." The second conclusion was: "That the necessity of any such exposure "is avoided by the conveyance of sewer water in closed, im-"permeable pipes underground, and by its distribution by "steam power, or by gravitation through pipes by jets, "after the method of distribution of garden watering, or "by shedding from a hose, whereby the extent of exposure "to evaporation is so far reduced in amount and time, and "the absorption by the land so immediate, that it is, as in "garden cultivation, inappreciable in its effect on the "atmosphere, or on the health of persons exposed to it." Other conclusions dealt with the agricultural advantages likely to ensue from the proposed method of applying town manure.

26. That is the first time that anything in the shape of deodorisation is mentioned at all, is it?—Certainly, yes. I may also mention that this suggestion as to the underground pipes and the jets probably had in view an experiment which about that time was being tried on a very extensive scale in the Metropolis.

27. Yes?—An experiment for taking sewage from some Pimlico sewers to the market gardens at Fulham by a company with a considerable capital for those times.

28. Now the end of the first period was 1857. Are there facts of importance which you associate with that year?—In connection with the last year of the first of the three periods which I have already mentioned, two important facts have to be noticed. The first is the presentation of a report dated March 1857, by Mr. Henry Austin, who was Chief Superintending Inspector of the General Board of Health, on the means of deodorising and utilising the sewage of towns. The second is the appointment on the 5th of January 1857 of a Royal Commission to inquire into the best mode of distributing the sewage of towns, and applying it to beneficial and profitable uses.

29. What have you to say about the report of Mr. Austin?—The report is arranged under the following heads:—(1) The constituents of sewage and their value; (2) a description of the chief processes adopted for deodorising sewage, and for manufacturing therefrom a solid manure; (3) a description of the means practised for the application of sewage to agriculture in the liquid form, and (4) the agricultural results of these various processes and recommendations as to the best means of realising the value of sewage whilst securing the removal of all danger to the public health.

30. In this division of the subject, what was included under the second head?—Under the second head (deodorisation and solid manure) Mr. Austin groups three classes of operations:—(1) The precipitation of the solid matters held in mechanical suspension and partial solution in the water, by the addition to the sewage of various chemical ingredients; (2) the separation of the solid matters in suspension by straining or filtration, and their admixture with various solid deodorisng materials; and (3) simple deposition and draining-off of the liquid from the solid mass. Among chemical processes, Mr. Austin describes methods of treatment by lime, by lime in addition to sulphate of alumina, by sulphate of iron and burnt magnesian limestone, by hydrochloric acid with chloride of sodium and protosulphate of iron, by sulphurous acid and carbolic acid with magnesia and lime, by sulphate of iron and animal charcoal, and by sulphate of iron and lime.

31. Do you understand that he tested all these processes?—Hardly; I think not.

32. No?—I rather think he relied upon the experiments of others.

33. Would you give an account of what was discussed under the third head, which dealt with the utilisation of sewage in the liquid form?—Under the third head, Mr. Austin discusses (1) the system of open irrigation, and (2) the system of underground pipes and distribution by movable hose and jet. Examples of the first method were the Craigentinny Meadows at Edinburgh, an experiment at Tavistock, on a farm at Harrow, at Exminster Lunatic Asylum, at Crediton, and extensive irrigation of meadows in Lombardy. Of the system of underground pipes with movable hose and jet instances are given at various farms, the abandoned works of the Metropolitan Sewage Manure Company at the Fulham Market Gardens, works at Dartmoor Prison and Colney Hatch Lunatic Asylum, and the towns of Rugby, Rusholme, and Watford.

34. What were the chief conclusions which Mr. Austin embodied in his report?—The chief conclusions were as follows:—That to avoid all further risk of injury to health, whether from discharge of the sewage into rivers and streams, or from its application to the land, it appeared desirable that the solid matter should in every case be separated from the liquid sewage at the outfall, and that a cheap portable manure should be manufactured therefrom for use in the immediate neighbourhood: That the liquid portion of the sewage, still retaining its chief value as manure, might then be applied with benefit to neighbouring lands: That the distribution by hose and jet by underground pipes had been found to be most advantageous: That upon grass lands larger quantities might be economically distributed by a combination of the underground pipe system, with subsidiary open irrigation by small contour gutters: That in any neighbourhoods where no opportunity existed for beneficial irrigation the liquid sewage before being discharged into rivers or streams

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should, after separation of the solid matter, be treated with lime or other deodorising and precipitating agents.

35. The appointment of the first Sewage Commission belongs to the year 1857. When was their first report made?—The preliminary report of the first Sewage Commission was made on the 26th March, 1858.

36. And what have you got to say about that preliminary report?—From this report it appears that the Commissioners had construed the reference as requiring them not only to consider the application of sewage to agriculture, "but further to examine the position in which town "populations are placed with regard to the disposal of "their sewage, and to devise, if possible, some means of "relieving them from the very serious difficulties under "which they now labour in this respect." "We felt," said the Commissioners, "that in order to fulfil the whole "intention of the inquiry entrusted to us, it would be "necessary not only that we should visit and personally "examine the different localities where sewage is em-"ployed in agriculture, or treated with a view of neutra-"lising its offensive and noxious properties, but that a "series of distinct experiments should be undertaken to "test the efficacy of existing methods, and, if possible, to "improve upon them." The second branch of the subject, viz., that concerned with the experiments, was reserved for future reports. The preliminary report, in addition to an outline of a scheme for dealing with metropolitan sewage, comprised the results of inspections and inquiries by a committee of five as regards all works then in operation. The remarks on these results were grouped under the headings:—Application of sewage by irrigation: Application of sewage by hose and jet: and precipitation of the solid matter of sewage.

37. Would you state what were the chief conclusions of the preliminary report?—The principal conclusions were: That the application of the whole sewage to land while profitable in certain cases was not, when conducted with moderate care, productive of nuisance or injury to health; that when circumstances prevented the disposal of sewage by direct application to land, the processes of precipitation would greatly ameliorate and practically obviate the evils of sewage outfalls, especially where there were large rivers for the discharge of the liquid; and that considered merely as the means of mitigating a nuisance these precipitating processes were satisfactory. There was one other conclusion which, perhaps, deserves quotation. This was: "That there is good ground for believ-"ing that the methods yet proposed for dealing with "sewage are not the best that can be devised, and that "further investigation will probably result in the discovery "of processes more thoroughly equal to the suppression of "the nuisance, and at the same time calculated to give "more valuable products."

38. Then I believe legislation followed soon after this preliminary report. Have you any observations to make upon the effect of such legislation?—On the 2nd of August in the same year (1858) was passed the Local Government Act, 1858. This, as its title shows, was an Act to amend the Public Health Act, 1848, and to make further provision for the local government of towns and populous districts. The most prominent feature in this Act in relation to the subject which we are now considering was an elaboration of the idea of sewage disposal on the basis of utilisation.

39. Will you give us some account of the provisions in the Act of 1858 which were concerned with sewage utilisation?—In their report of 1854 the first General Board of Health had suggested an amendment of the Act of 1848 to facilitate the application of sewage manure to lands. The General Board of Health had also referred to the difficulties of local authorities on account of their want of legal powers for carrying sewer pipes beyond their immediate jurisdiction. Section 30 of the Local Government Act, 1858, was designed to amplify the powers of local authorities for these purposes. Accordingly it enacted that the powers given to local authorities by Section 46 of the Act of 1848—powers which, it may be remembered, included that of causing sewers to communicate with and be emptied into fit and necessary places—might be exercised also without the district if necessary for the purpose of outfall and distribution of sewage, upon making due compensation. Section 30 of the Local Government Act, 1858, further enabled the local authority: (*a*) to contract with any company or person for the sale of sewage, or for the distribution of it over any land, and (*b*) to contract for, purchase, or take on leases any lands, buildings, engines, materials, or apparatus for the purpose of receiving, storing, disinfecting, or distributing sewage. But the things authorised by the Section were to be done so as not to create a nuisance.

40. Did the Act deal in any way with the question of river pollution?—Yes. The Act made new provisions for the protection of interests in rivers and streams. Section 73, in particular, provided that nothing in the Act, or any incorporated Act, should be construed to authorise a local authority to injuriously affect any river or stream, or its feeders, or the supply, quality, or fall of water, without the previous consent in writing of any company or individuals entitled to prevent or be relieved against such injury.

41. Going in order of date, what is the next fact to which you wish to draw attention?—On the first of August, 1861, was passed the Local Government Act (1858) Amendment Act (1861). This contains a provision of great importance, I think, in relation to the subject now under consideration. The importance consists in the first definite imposition of a restriction designed to secure the purification of sewage effluent before discharge into streams.

42. Well, perhaps you will give us some account of that restriction?—The Section (4) which imposed the restriction in question amplified the powers which the Local Authority derived from Section 45 of the Public Health Act, 1848, with regard to the construction, repair, improvement, etc., of sewers by enabling them to exercise these powers without their district "for the purpose "of outfall or distribution of sewage." The proviso to the Section was in these terms: "Provided always that "nothing herein contained shall give or be construed to "give power to any Local Board to construct or use any "outfall drain or sewer for the purpose of conveying "sewage or filthy water into any natural water course or "stream until such sewage or filthy or refuse water be "freed from all excrementitious or other foul or noxious "matter such as would affect or deteriorate the purity "and quality of the water in such stream or water-course."

43. Have you anything further to note under 1861?—In this same year, also in the month of August, was made the Second Report of the Royal Commission. This report embodied (1) the results of the examination by Committees of the state of the rivers receiving the sewage of large towns, and (2) the results of the investigations and experiments which up to that time had been undertaken, at the instance of the Commission, to test the efficacy of existing or improved methods of sewage disposal.

44. And what is the effect of the Commissioners' report under the second of the two heads which you have just mentioned?

45. (*Professor Ramsay.*) Might I interrupt? Might I ask the year, please?—1861. With regard to the second of these branches of their inquiry the Commissioners prefaced their detailed observations with the following:—"In our former report we stated, and we have since seen "nothing which should induce us in any degree to alter "that opinion, that to obtain the greatest amount of good "from the utilisation of sewage as a manure, concur-"rently with the fullest immunity from the evils arising "from its discharge into rivers as a noxious and pestilen-"tial liquid, to obtain the good and avoid the evil, one "only thoroughly efficient mode of treatment could be "prescribed—that, namely, of its direct application to "land in the liquid form." At the same time the Commissioners recognised the importance of the consideration that other means of dealing with sewage should be at the command of such towns as from local circumstances might be unable to adopt the liquid method of distribution. As to the irrigation process, experiments were then in progress, but they were in a position to arrive at a decision as to the relative merits of the processes by which sewage could be rendered less injurious. Accordingly, they discussed in detail various methods of deodorisation, their general conclusion being that, among deodorisers the material which up to that time had been found to be the best for the purpose was perchloride of iron; but that in many cases the employment of the cheaper material, lime, might suffice.

46. (*Chairman.*) That disposes of 1861. Have you anything to note under the next year?—On the 18th of February, 1862, the House of Commons appointed a Select Committee to inquire into the best means of utilising the sewage of the cities and towns of England, with a view to the reduction of local taxation and the benefit of agriculture. On the 10th of April the Committee made their first report in these terms:—"That it is the opinion of this Committee: 1. That careful and "exact experiments are necessary to elucidate the

"agricultural value of sewage and the best mode of apply-
"ing it. 2. That such experiments have been carried
"on at Rugby by the Commission appointed to inquire
"into the best mode of distributing the sewage of towns
"and applying it to beneficial and profitable uses; and
"(3) that it is desirable that these experiments shall be
"continued during the present year."

47. I believe they made a further report in the same year; can you tell us the conclusions of that report?—Yes; on the 29th of July, 1862, the Committee made a second report. Their principal conclusions were: that the value of sewage varied greatly, but that when the manure and other fertilising refuse were not diluted in an unusual degree, the sewage was of great agricultural value: that the cost of the application of sewage depended upon the relation of the town to the surrounding agricultural lands, and to their value and quality; but, when these relations were not unusually adverse to the application of the sewage, it could be applied for agricultural purposes with profit either to the town or to the owners of the land; and that Municipal Authorities had not sufficient powers to enable them to rent or otherwise deal with lands in their neighbourhood for the most profitable application of the sewage in relief of local taxation.

48. What is the next event in your chronological summary?—On the 26th of April, 1864, the House of Commons appointed a Select Committee to inquire into any plans for dealing with the sewage of the Metropolis and other large towns with a view to its utilisation for agricultural purposes. This Committee reported on the 14th of July, 1864.

49. And have you anything to say about the effect of the Committee's report?—Yes. Among the conclusions embodied in the report the following may be specially noted:—"Your Committee has come to the conclusion
"that it is not only possible to utilise the sewage of towns
"by conveying it in a liquid state through mains and
"pipes to the country, but that such an undertaking may
"be made to result in pecuniary benefit to the ratepayers
"of the towns whose sewage is thus utilised. . . There
"can be no doubt as to the injury which results from the
"practice of conducting sewage and other refuse matters
"into the rivers from whence numerous towns, villages,
"and country populations derive their water supply.
"It is imperatively necessary that such a practice
"should be discontinued. No efficient artificial method
"has been discovered to purify, for drinking and culinary
"purposes, water which has been once infected by town
"sewage. By no known mechanical or chemical means
"can such water be more than partially cleansed; it is
"always liable to putrify again. Processes of filtering
"and deodorisation cannot, therefore, be relied upon to
"do more than mitigate the evil. Water which appears
"perfectly pure to the eye is sufficient, under certain
"conditions, to breed serious epidemics in the population
"which drinks it. Soils, however, and the roots of
"growing plants, have a great and rapid power of ab-
"stracting impurities from sewage water and rendering
"it again innocuous and free from contamination. . . .
"If the sewage of towns is no longer to flow into rivers,
"the only alternative which remains is to dispose of it
"on the land." The Committee then dealt with certain suggestions for the protection of rivers, and recommended legislation for freeing the basins from pollution. Such legislation, they considered, should include a provision for compelling Local Boards to render the sewage of their districts innocuous by application to the land for agricultural purposes.

50. Have you anything to note in 1865?—On the 3rd March, 1865, a Parliamentary Paper (105) was presented as a return to an address of the House of Commons for a copy of all Memorials and Petitions to Her Majesty's Government on the subject of the pollution of rivers, or the utilisation of sewage. The Memorials included in this return were from Birmingham, Huddersfield, Nottingham, Rotherham, Sheffield, and York. The general tenor of the Memorials was in favour of legislation to provide for the land treatment of sewage, and for preventing its discharge into streams.

51. In this same year, 1865, the Royal Commissioners reported again, did they not?—Yes; they made their third and last report.

52. And in their final report, what were the conclusions?—The Commissioners said that as the result of their labours, extending over eight years, they had confidence in submitting certain conclusions, of which the first and most important may be quoted *in extenso*. This was as follows:—"The right way to dispose of town sewage is
"to apply it continuously to land, and it is only by such
"application that the pollution of rivers can be avoided."
The second conclusion referred to the different financial results of the land treatment of sewage under different local circumstances. The third conclusion affirmed that in favourable circumstances there might be a profit; and that, under opposite circumstances, the rate to c ver loss need not be of large amount.

53. Was this report followed by legislation?—Yes. A few months after the issue of the last report of the Royal Commission, viz., on the 29th of June, 1865, was passed the Sewage Utilisation Act 1865 (28 and 29 Vict. c 75).

54. And what have you to note concerning that Act?—The preamble recited that it was expedient to remove difficulties under which Local Boards and other bodies having the care of sewers laboured in disposing of the sewage of their Districts so as not to be a nuisance, and to give facilities to such Authorities to make arrangements for the application of such sewage to land for agricultural purposes. Previous legislation had been concerned with the requirements of towns in this matter. The Act of 1865 extended to rural areas as well. The chief provisions in relation to the subject now under consideration were those which gave Sewer Authorities the power of combination (s. 9), the power, with the sanction of the Attorney General, to proceed for the purpose of protecting water courses from pollutions arising from sewage (s. 10), and the power of agreement for the supply of sewage for a period not exceeding twenty-five years (s. 14). There was also a provision that nothing in the Act or in the Acts to which it referred should authorise a sewer authority to make a sewer so as to drain direct into any stream or water-courses (s. 11).

55. I believe the Act of 1865 was the first of a series. Can you state shortly the chief points of interest in relation to the other enactments of the series?—In certain details, of no great importance as regards the present subject of investigation, the Sewage Utilisation Act, 1865, was amended by the Sanitary Act, 1866. It may, however, be noted that this Act for the first time gave power to the Central Authority, by section 49, to take action against a Local Authority of whom complaint was made of default in providing its district with sufficient sewers, or in the maintenance of existing sewers. In the following year (1867) another Sewage Utilisation Act (the 30 and 31 Vict., c. 113) contained a series of new provisions, of which some mention may be made. Section 3 gave the Sewer Authority power to do outside what it could do within its district for the purpose of receiving, storing, disinfecting, or distributing sewage. Section 4 gave the Authority power to purchase or take on lease lands within or without its District. Section 5 enabled the Authority (a) to lease their land for not more than seven years for agricultural purposes; (b) to contract with some person to take the whole or a part of the produce; or (c) to farm the land and dispose of the produce. These alternative powers were subject to the restriction that the provision to be made should extend to the whole of the sewage. A series of provisions in sections 10 to 14 dealt with the formation of United Districts to be placed under the jurisdiction of Joint Sewerage Boards. And Section 15 gave the Sewer Authority extensive powers of contributing to the expenses of persons contracting to take a supply of sewage. In the next year (1868) an Act to amend the Sanitary Act, 1866, contained provisions for the extension of the powers of the Central Authority in dealing with defaulting Local Authorities. And here—to dispose of enactments of this class—it may be noted that legislation with the same object is the chief feature in the Sanitary Loans Act, 1869, and the Sanitary Act, 1870.

56. Apart from legislation, is there any other circumstance connected with the year 1868 to which you wish to refer?—The most important circumstance to be mentioned in connection with the year 1868 is the appointment on the 6th of April of a Royal Commission to inquire into the best means of preventing the pollution of rivers. An earlier attempt at such investigation had been made by the appointment of a Royal Commission in 1865; but after the presentation of some reports, the contents of which do not appear to require special consideration in connection with the present subject, the disagreement of the Commissioners had led to the revocation of the warrant. The Second Commission consisted of Sir William Thomas Denison, Mr. (now Sir Edward) Frankland, and Mr. John Chalmers Morton.

57. Only three members?—That is all; only three; and there were also only three in the first Rivers Pollution Commission.

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58. Only three again?—Yes; Mr. (afterwards Sir Robert) Rawlinson, Professor Way, and Mr. Thornhill Harrison.

59. What were the terms of the reference to the Commissioners—the Rivers Pollution Commission of 1868?—They were to inquire—(1) How far the present use of rivers or running waters in England for the purpose of carrying off the sewage of towns and populous places, and the refuse arising from industrial processes and manufactures, could be prevented without risk to the public health or serious injury to such processes and manufactures; (2) how far such sewage and refuse could be utilised and got rid of otherwise than by discharge into rivers or running waters, or rendered harmless before reaching them. The Commissioners were told to act upon the instructions issued to their predecessors. In these instructions (dated the 30th of May, 1865) the following passage seems to deserve mention:—"Although it may "be taken as proved generally that there is a widespread "and serious pollution of rivers, both from town sewage "and the refuse of mines and manufactories, and that "town sewage may be turned to profitable account as a "manure, there is not sufficient evidence to show that "any measure absolutely prohibiting the discharge of "such refuse into rivers, or absolutely compelling town "authorities to carry it on the lands, might not be remedy-"ing one evil at the cost of an evil still more serious in "the shape of injury to health and damage to manufac-"tures."

60. It will perhaps be convenient to leave the chronological order for a moment to summarise the results of the labours of the second Rivers Pollution Commission?—Yes. Their first report—and this, I think, may conveniently serve to mark the beginning of the last of the three periods to which I have already referred—was made in February, 1870. An introduction described the general method of procedure of the Commissioners. This comprised the inspection of all places where any attempt had been made to purify water polluted by sewage or manufacturing refuse; and the examination of the different processes—first, with reference to their efficiency as means of cleansing water so contaminated; second, with reference to their cost; and such examination included analyses and experiments by the Commissioners themselves, as well as the collection of evidence from other sources. Among other experiments may be mentioned those which established the value of the method of land treatment which is now known as intermittent downward filtration.

61. What is the effect of the Commissioners' first report as to the various processes of sewage treatment?—The effect of the Commissioners' summary of the comparative merits of the three classes of processes for the treatment of sewage, viz., chemical, filtration, and irrigation, may be stated thus: (1) All these processes are to a great extent successful in removing polluting organic matter in suspension. But filtration is best, irrigation ranks next, and the chemical processes are less efficient. (2) But for removing organic matters in solution the processes of downward intermittent filtration and irrigation are greatly superior to upward filtration and chemical processes. Twice as much polluting matter is removed by downward intermittent filtration and irrigation, and looking only to purity of effluent water it would be difficult to decide between these two methods. But—the Commissioners said—there are obvious reasons why the latter (irrigation) must in all but very rare and exceptional instances be preferred on economical grounds. Intermittent filtration is a costly process with no possibility of any return, whilst irrigation, although it may in the first instance require a larger outlay of capital, affords a hopeful prospect of a return for the capital invested.

62. What had they got to say about manufacturing pollutions?—With regard to manufacturing pollutions the following observations of the Commissioners may be quoted:—"Of the many polluting liquids which now "poison the rivers of the Mersey and Ribble basins we "feel ourselves justified in stating that there is not one "which cannot be either kept out of the streams altogether "or so far purified before admission as to deprive it of "its noxious character, and this not only without unduly "interfering with manufacturing operations but even in "some instances with a distinct profit to the manufacturer; "and even in those cases where a certain amount of "expense must be incurred in unremunerative operations "the use of the purified stream will more than recompense "this expenditure."

63. The second report of the Rivers Pollution Commissioners was also, I believe, made in 1870. Have you any remarks upon that report?—The second report of the Rivers' Pollution Commissioners was concerned with a detailed examination of the A.B.C. process. In this report the following passages occur: "We are compelled to admit "that the present resources of this science (chemistry) hold "out no hope that the foul matters dissolved in sewage will "be precipitated and got rid of by the application of chemi-"cals to the offensive liquid." Concerning irrigation, even after experiments with strong raw sewage on a stiff clay land, the Commissioners say: "We have never taken a "sample of effluent sewage that had been subjected on "a working scale to any other cleansing process, which "was not still so highly charged with putrescible animal "matters as to be utterly unfit for admission into running "water. Irrigation is the only process of cleansing sewage "which has stood the test of experience, and unless it be "extensively adopted there is but little hope of any sub-"stantial improvement in our sewage polluted rivers."

64. Have you any remarks to make on the subsequent reports?—The third report of the Commissioners was published in 1871. It was concerned largely with pollution by the refuse of woollen manufacture. Their general conclusion was favourable to irrigation and intermittent filtration as appropriate cleansing processes. The Commissioners added that where these remedies could not be adopted the foul liquids might be got rid of by evaporation. The fourth report of the Commissioners was issued in 1872. It dealt in the main with various Scottish rivers; but it contained conclusions and recommendations of general application. Among these were—(1) The suggestion of certain revised standards of purity; and (2) the expression of the Commissioners' opinion that any law having for its object the prevention of river pollution should: (*a*) enact these standards of purity below which any liquid discharges into water courses should be forbidden; (*b*) give power to all manufacturers in towns, except those of gas, paraffin oil, pyroligneous acid, and animal charcoal, and workers in metals, to discharge their drainage waters into the town sewers under suitable regulations; and (*c*) confer additional powers on corporations, local boards, manufacturers, and others to take land compulsorily under Provisional Order for the purpose of cleansing sewage or other foul liquids, either by irrigation, filtration, or otherwise. The fifth and last report was published in 1874. It dealt mainly with river pollution from mining operations, and from various kinds of industry connected with metals.

65. That deals with all the reports of the Rivers' Pollution Commission, does it not?—Yes.

66. But there was another Royal Commission going on during the same period, was there not?—Yes. While the Rivers Pollution Commissioners were pursuing their investigations there had been appointed in 1869 another Royal Commission to inquire into and report upon the operation and administration of the sanitary laws outside the Metropolis. In their second report, which was issued in 1871, the Sanitary Commission said that on the subject of sewage disposal they forbore to recommend any mode of operation. They added: "Your Majesty has commis-"sioned others to report on this important subject. We "leave authorities in dealing with this and other large "sanitary requirements to carry out the best known "methods." A result of the recommendations of the Sanitary Commission was the constitution of the Local Government Board. The Act for this purpose was passed on the 14th of August 1871.

67. Under 1872 have you anything to note?—On the 10th of August, 1872, was passed the Public Health Act, 1872. This Act, which divided the country into urban and rural sanitary districts, very materially amended the existing law with regard to the formation of united districts having for their objects (*inter alia*) the making of main sewers or the carrying into effect of systems of sewerage for the constituent areas. Additional facilities were also given for the communication of the sewers of a district with those of a subjacent district for purposes of outfall and reception, disinfection, distribution, and disposal of sewage.

68. So far as concerns the subject of rivers pollution the Bill for the Act of 1872 was of wider scope than the Act itself?—Yes. The Bill for the Public Health Act, 1872, had embodied proposals for a more extensive amendment of the law than Parliament at the time was prepared to accept. By the Bill as introduced it was proposed to take power by Provisional Orders to form united districts for the prevention of the pollution or of the obstruction of any streams. Further, the Bill proposed prohibitions against putting solid matters, sewage, or manufacturing refuse into streams. It also proposed, following the recommendation of the Rivers' Pollution Commissioners in their fourth report, to prescribe certain detailed standards

of pollution, with power to the Local Government Board to vary these standards. Further, the Bill proposed that it should be the duty of every sanitary authority to cause to be analysed in conformity with the directions of the Local Government Board, any sewage matter, or filthy or noxious water or washings of manufactories or other polluting liquid falling or flowing into any stream within the district of the sanitary authority.

69. Have you anything to record under 1873?—In 1873 another attempt was made in a separate Bill—the Pollution of Rivers Prevention Bill—to obtain Parliamentary sanction to provisions which in an amended and extended form reproduced the substance of some of the clauses which had been withdrawn from the Public Health Bill of 1872. This Bill of 1873 again embodied a scale of definitions of polluting liquids. The Bill was referred to a Select Committee of the House of Lords. Much of the evidence before the Committee was addressed to the support of and objection to the proposed standards. The Bill was reported to the House with amendments; but no further progress was possible.

70. And what are the next dates to which you refer?—In 1875 there was an important measure of consolidation, viz., the Public Health Act, 1875, and in 1876 the Local Government Board issued the Report of a Committee appointed by the President to inquire into the several modes of treating town sewage. For the present purpose it may be thought that, as unofficial opinion was not represented on the Committee, its conclusions need not be discussed in any detail. I therefore confine myself to the mention of the facts of the appointment of the Committee and its report. Also in 1876 was passed the Rivers Pollution Prevention Act, 1876.

71. Then you have nothing further, I think, to note until you reach the year 1882?—On the 22nd of June, 1882, was appointed a Royal Commission to "inquire into "and report upon the system under which sewage is dis-"charged into the Thames by the Metropolitan Board of "Works, whether any evil effects result therefrom, and "in that case what measures can be applied for remedying "or preventing the same."

72. When did that Commission make its first report?—The first report of the Commission which bears date the 31st of January, 1884, related solely to the metropolitan system of sewage disposal and its effects.

73. The second report was also made in 1884, was it not?—Yes. The second and final report is dated the 27th of November, 1884. It deals with remedial measures. In this respect it has more than a metropolitan interest. It contains in particular much valuable information upon the general aspect of the question of the disposal of town sewage with a summary of former inquiries and discussions on the subject. It then describes the proceedings of the Commission, which included the examination of many technical witnesses and visits to various towns.

74. Would you state the effect of the conclusions of the Commissioners as far as they bear on the subject for our consideration?—The report gives the conclusions of the Commission with regard to methods of treatment—(1) By broad irrigation, (2) by filtration through land, (3) by processes of deposition or precipitation, (4) by precipitation supplemented by application to land. Eliminating from the Commissioners' conclusions those which have a special reference to the case of the metropolis, I think that the following passages may be selected as deserving of quotation. As to broad irrigation, the Commissioners say:—"Although there are many points in regard to this system "in which the authorities differ in opinion, there can be "no doubt of the general conclusion: That the results of "experience and of the investigation of the subject by the "most competent authorities have been strongly and "almost unanimously in favour of the application to land "as in every respect the best and most advisable mode of "treating sewage, when circumstances will admit of its "use." As to the efficiency of purification with this system the Commissioners observe (par. 206): "The evi-"dence shows that there can be no doubt as to the effi-"cient purification when the works are proper and the "management is careful. This, indeed, is sufficiently "proved by the fact that the effluent under these con-"ditions is considered suitable to be allowed to flow into "running streams from which water supply is drawn." The Commissioners also were of opinion that this method of treatment need cause no danger to health; that with proper care when applied on a moderate scale it need cause no serious nuisance to the surrounding neighbourhood, but that if improperly managed nuisance may arise and may become considerable; and that there may be a danger of the pollution of subsoil waters.

75. What had they to say as regards land filtration?—They said they were of opinion:—"(1) That the process "has great scientific merit, and offers valuable practical "advantages for the disposal of sewage in situations where "broad irrigation is impracticable, and where land suit-"able for filtration can be obtained; (2) That, however, it "appears desirable, when the area of land is considerably "reduced, that the sewage should be previously treated "by some efficient process for removing the sludge."

76. And what were their conclusions respecting the methods of deposition or precipitation?—With regard to the methods of deposition or precipitation, the Commissioners point out that by chemical precipitation, the suspended matters may be almost entirely removed, or in other words the sewage may be practically clarified (p. liii.). They further say that "it seems also to be the "general opinion that the chemical processes in their best "form will also have some effect in removing noxious "matter in solution." But they add that "all agree that "a considerable amount of polluting matter must be left "in the effluent."

77. They also stated their views, I believe, with regard to precipitation processes combined with land treatment?—As to precipitation supplemented by application to land, the following quotations may suffice to indicate the Commissioners' opinions.

"In discussing the treatment of sewage by chemical "precipitation we have pointed out that the clarified "liquid, though improved, still contains a considerable "amount of impurity. And we have also noticed the "remarkable effect of application to land in purifying "sewage water from its noxious properties. Hence it is "a natural inference that if these two processes could "be combined, that is to say, if after chemical clarification "the still impure liquid could be applied to land, the "purification would be completely effected, and at the "same time some advantage might be gained by the utilisa-"tion of the fertilising matter.

. . . . . .

"The application to land might be either by surface "irrigation or by the newer process of filtration through "porous beds, the latter being, however, by far the more "advisable for the purpose when suitable land can be "found. For, since the grosser impurities have already "been abstracted, the complete purification might be "effected by a smaller area of land than when the whole "contents of the sewage had to be dealt with."

Finally, in their general conclusions and recommendations the Commissioners, referring to the liquid effluent from a precipitation process, say:—

"We believe that the liquid so separated would not be "sufficiently free from noxious matters to allow of its "being discharged at the present outfalls (*i.e.*, into the "Thames) as a permanent measure. It would require "further purification; and this, according to the present "state of knowledge, can only be done effectually by its "application to land."

78. Now you are drawing very near the end of your chronological summary. Are there any further facts to record?—On the 18th of August, 1890, was passed the Public Health Acts Amendment Act, 1890. This is an adoptive Act. It deserves mention on account of provisions, which will be detailed hereafter in the summary of the existing law, for the prohibition of the discharge into sewers of chemical refuse, waste steam, etc. On the 27th of July, 1893, was passed the Rivers Pollution Prevention Act, 1893. The object of this measure was to make it quite clear that the offence of permitting sewage to pass into a stream could be established against a sanitary authority even though the sewers vesting in the Authority had been constructed before the passing of the Public Health Act, 1875.

79. You are now, Mr. Adrian, I think, about to state, with some needful commentary, the effect of the existing law with reference to sewage disposal. Would you say, in the first place, where the general statute law is to be found?—It may be said that, for all practical purposes, the general law relating to sewage disposal in England and Wales is to be found in the Public Health Act, 1875, supplemented by the Rivers Pollution Prevention Acts.

80. And what are your remarks on the Public Health Act of 1875?—The Public Health Act, 1875, being a consolidating Act, contains provisions which, if traced to their origin, are seen to belong to the legislation of some

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one or other of the three periods already mentioned, and reflect, even in their present context, the prevailing ideas and aims of the period. Thus, when we attempt a broad classification of the law by reference to the powers which it confers, and the restrictions which it imposes, we observe that, although the powers as now used may be made to subserve the modern purpose of river protection, they are fundamentally the outcome of a system of utilisation, or of the profitable application of sewage.

81. Would you give the effect of the provisions which you arrange in the first class—that is, that which relates to the powers of local authorities?—I first refer to the provisions grouped under the heading, "Disposal of Sewage." These sections provide as follows:—Section 27. "For the purpose of receiving, storing, disinfecting, "distributing, or otherwise disposing of sewage, any local "authority may (1) Construct any works within their "district, or (subject to the provisions of this Act as to "sewage works without the district of the local authority) "without their district; and (2) contract for the use "of, purchase, or take on lease any land, buildings, "engines, materials, or apparatus either within or with-"out their district; and (3) contract to supply for any "period not exceeding twenty-five years any person with "sewage, and as to the execution and costs of works, "either within or without their district, for the purposes "of such supply, provided that no nuisance be created in "the exercise of any of the powers given by this section."

Section 29. "Any local authority may deal with any "lands held by them for the purpose of receiving, storing, "disinfecting, or distributing sewage in such manner as "they deem most profitable, either by leasing the same "for a period not exceeding twenty-one years for agri-"cultural purposes, or by contracting with some person "to take the whole or a part of the produce of such land, "or by farming such land and disposing of the produce "thereof; subject to this restriction, that in dealing with "land for any of the above purposes provision shall be "made for effectually disposing of all the sewage brought "to such land without creating a nuisance."

Section 30. "Where any local authority agree with any "person as to the supply of sewage, and as to works to "be made for the purpose of such supply, they may con-"tribute to the expense of carrying into execution by such "person all or any of the purposes of such agreement, "and may become shareholders in any company with "which any agreement in relation to the matters "aforesaid has been or may hereafter be entered "into by such local authority, or to, or in which "the benefits and obligations of such agreement may have "been or may be transferred or vested."

82. Do you note any subsidiary provisions in connection with the sections conferring the powers which you have just described?—The exercise of powers of this description is obviously facilitated by enlarging the ability of the individual landowner to construct the works needed for the efficient distribution of the sewage supply over his land. Accordingly Section 31 provides that "the making of works "of distribution and service for the supply of sewage to "lands for agricultural purposes shall be deemed 'an "improvement of land' authorised by 'The Improvement "of Land Act, 1864,' and the provisions of that Act shall "apply accordingly," and these provisions have been extended by subsequent legislation, *e.g.*, The Settled Land Act, 1882, the detailed effect of which need not for the present purpose be specially discussed.

83. Then what is the next point you would wish to mention in connection with the powers of a local authority?—It was recognised at an early date that the operations of a local authority were often seriously hampered by restricting the exercise of their powers to the limits of their own district. The law accordingly provides (1) for separate action by the local authority beyond its district; (2) for combination of local authorities by agreement, with or without the control of the central authority; (3) for combination, with the aid of the central authority, in the more permanent form of a Union of districts; the needful powers and duties being assigned to a joint board, constituted by Provisional Order, of representatives of the combining areas.

84. What example can you give of the first of the three modes of action?—An example of the first method of procedure, viz., of separate action by a local authority beyond the limits of its district, is to be found in the sections headed "As to Sewage Works without District," which are as follows:—Section 32: "A local authority "shall, three months at least before commencing the con-"struction or extension of any sewer or other work for "sewage purposes without their district, give notice of "the intended work by advertisement in one or more "of the local newspapers circulated within the district "where the work is to be made. Such notice shall de-"scribe the nature of the intended work, and shall state "the intended termini thereof, and the names of the "parishes, and the turnpike roads and streets and other "lands (if any) through across under or on which the work "is to be made, and shall name a place where a plan of the "intended work is open for inspection at all reasonable "hours; and a copy of such notice shall be served on the "owners or reputed owners, lessees or reputed lessees, "and occupiers of the said lands, and on the overseers "of such parishes, and on the trustees, surveyors of high-"ways, or other persons having the care of such roads or "streets."

Section 33: "If any such owner, lessee or occupier, or "any such overseer, trustee, surveyor, or other person "as aforesaid, or any other owner, lessee or occupier who "would be affected by the intended work, objects to "such work, and serves notice in writing of such objec-"tion on the local authority at any time within the said "three months, the intended work shall not be com-"menced without the sanction of the Local Government "Board after such inquiry as hereinafter mentioned, "unless such objection is withdrawn."

Section 34: "The Local Government Board may, on "application of the local authority, appoint an inspector "to make inquiry on the spot into the propriety of the "intended work and into the objections thereto, and to "report to the Local Government Board on the matters "with respect to which such inquiry was directed, and "on receiving the report of such inspector, the Local "Government Board may make an order disallowing or "allowing, with such modifications (if any) as they may "deem necessary, the intended work."

In connexion with these provisions may be noted Section 16 of the Act, the first paragraph of which confers the necessary powers for enabling the local authority to carry sewers through, across, or under any road or street, or place intended for a street, or under any cellar or vault which may be under the pavement or carriageway of any street, and into, through, or under any lands within their district. The section provides that the local authority "may also (subject to the provisions of this Act "relating to sewage works without the district of the local "authority) exercise all or any of the powers given by this "section without their district for the purpose of outfall or "distribution of sewage."

85. Now we come to the second mode of action. What are the provisions relating to this matter?—In illustration of the second course of proceeding, viz., voluntary combination of local authorities, may be noted Section 28, which provides that:—"The local authority of any dis-"trict may, by agreement with the local authority of any "adjoining district, and with the sanction of the Local "Government Board, cause their sewers to communicate "with the sewers of such last-mentioned authority, in "such manner, and on such terms, and subject to such "conditions as may be agreed on between the local autho-"rities, or, in case of dispute, may be settled by the "Local Government Board, provided that so far as prac-"ticable storm waters shall be prevented from flowing "from the sewers of the first-mentioned authority into "the sewers of the last-mentioned authority, and that "the sewage of other districts or places shall not be per-"mitted by the first-mentioned authority to pass into "their sewers so as to be discharged into the sewers of the "last mentioned authority without the consent of such "last-mentioned authority." Also under this head may be mentioned the wider power of Section 285, which provides that: "Any local authority may, with the consent "of the local authority of any adjoining district, execute "and do in such adjoining district all or any of such "works and things as they may execute and do within "their own district, and on such terms as to payment or "otherwise as may be agreed on between them and the "local authority of the adjoining district; moreover, two "or more local authorities may combine together for the "purpose of executing and maintaining any works that "may be for the benefit of their respective districts or "any part thereof."

86. Then how would you describe the third mode of procedure?—The more complete and lasting form of combination is that which ensues upon the formation of a united district under the jurisdiction of a Joint Board. The provisions relating to the constitution of united districts may thus be summarised:—Any one or more local authorities may apply to the Local Government Board

for the issue of a Provisional Order to form their districts or certain contributory places therein into a united district for (*inter alia*) the making of a main sewer or the carrying into effect of a system of sewerage for the use of all the districts or contributory places, or for any other purposes of the Public Health Act, 1875. The Local Government Board, upon receipt of the application, direct a local inquiry to be held, and if, upon a consideration of their inspector's report, it appears to the Board that it would be for the advantage of the districts, or any of them, or any parts thereof, or of any contributory places in any rural district or districts, that they should be formed into a united district, the Board may issue a provisional order providing for the union of the districts or contributory places. In such a case the united district would be governed by a Joint Board consisting of such number of representatives of each of the constituent authorities as might be provided by the Order. When the Joint Board has been constituted the local authorities having jurisdiction in the component districts or contributory places cease to exercise therein any powers, or to perform any duties, or to be subject to any liabilities or obligations which the Joint Board is empowered to exercise or perform or is made subject to; but the Joint Board may delegate to the local authority of any component district the exercise of any of its powers or the performance of any of its duties.

87. Would you proceed with the enumeration of the powers of the local authorities?—From the nature of the powers conferred upon the local authority for the purpose of sewage disposal it is manifest that facilities for the acquisition of land become of primary importance. Accordingly the Public Health Act provides by section 27 (2) that any local authority may for purposes of sewage disposal "contract for the use of, purchase, or take on "lease any land" . . . either within or without "their district." Provisions with respect to the purchase, leasing, sale, and exchange of lands for the purposes of the Act are also contained in sections 175 to 178. Of these the effect may be briefly stated as follows:—Section 175 which relates to voluntary transactions provides that any local authority may for the purposes of the Act purchase or take on lease, sell, or exchange any lands, whether situated within or without their district. They may also buy up any water-mill, dam, or weir which interferes with the proper drainage of or the supply of water to their district. To facilitate the acquisition of lands section 176 incorporates certain provisions of the Lands Clauses Acts. It also provides the means and prescribes the regulations in pursuance of which a local authority may, through the operation of a Provisional Order to be made by the Local Government Board, and to be confirmed by Parliament, be allowed to put in force the powers of the Lands Clauses Acts for the purchase of lands otherwise than by agreement. Section 177 provides for the letting, with the consent of the Local Government Board, of land which belongs to a local authority and can conveniently be spared. And section 178 facilitates the sale to local authorities of lands of the Duchy of Lancaster.

88. Have you anything to say about the financial aspect of the matter?—It is important for the success of undertakings on a scale adequate to the needs of each locality that a local authority should be in a position to obtain that relief of the financial burden which is the result of spreading capital outlay over a term of years. The Act consequently confers borrowing powers upon local authorities, subject to certain restrictions, and it also provides that the Public Works Loan Commissioners may advance the money to the authority at a low rate of interest. Some of the more important regulations affecting the loans of local authorities may be found in Section 234, and are thus summarised: (1) Money must not be borrowed except for permanent works (including under this expression any works of which the cost ought in the opinion of the Local Government Board to be spread over a term of years); (2) the sum borrowed must not at any time exceed, with the balances of all the outstanding loans contracted by the local authority under the Sanitary Acts and the Public Health Act, in the whole the assessable value for two years of the premises assessable within the district; (3) where the sum proposed to be borrowed with such balances (if any) would exceed the assessable value for one year of such premises, the Local Government Board shall not give their sanction to such loan until one of their inspectors has held a local inquiry and reported to the Board; (4) the money may be borrowed for such time, not exceeding sixty years, as the local authority, with the sanction of the Local Government Board, determine in each case. An exceptional method of raising money is also permissible where any local authority are possessed of any land, works, or other property for the purposes of disposal of sewage. Such an authority may borrow any moneys on the credit of and may mortgage their sewage lands. The moneys so borrowed must be applied for purposes for which moneys may be borrowed under the Public Health Act. This power of borrowing, where the sums borrowed do not exceed three-fourths of the purchase money of the lands, is to be deemed to be distinct from and in addition to the general borrowing powers conferred on a local authority by the Act (s. 235). Joint Boards have, for the purposes of their constitution, like powers of borrowing on the credit of any fund or rate applicable by them to purposes of the Public Health Act or on the credit of sewage land and plant as are conferred on local authorities (s. 244).

89. Before passing from the enumeration of the powers of local authorities you may wish to notice a few miscellaneous provisions?—Among minor matters auxiliary to a scheme of sewage disposal may be mentioned—(*a*) the power which local authorities possess under Section 51 of providing their districts or parts thereof with a supply of water proper and sufficient for public and private purposes; (*b*) the power of a local authority to take proceedings for protecting watercourses within their districts from pollutions arising out of sewage (s. 69); the power to enter, examine, or lay open any lands or premises for the purpose of making plans, surveying, measuring, taking levels, making, keeping in repair or examining works, etc., so often as may be necessary (s. 305); and the power to take proceedings against persons obstructing the local authority in the execution of their powers or damaging works or property belonging to them (Sections 306, 307, and 308).

90. Well, we come now to the provisions that may be classed as restrictive, and, first, will you deal with those in the Public Health Act?—The restrictions so far as the Public Health Act, 1875, is concerned, are those contained in Section 17 and in Sections 327 to 333. The first of these sections provides that "Nothing in this Act shall "authorise any local authority to make or use any sewer, "drain, or outfall for the purpose of conveying sewage or "filthy water into any natural stream or watercourse, or "into any canal, pond, or lake until such sewage or filthy "water is freed from all excrementitious or other foul or "noxious matter such as would affect or deteriorate the "purity and quality of the water in such stream or "watercourse or in such canal, pond, or lake." The remaining sections forbid the local authority to use, injure, or interfere with protective or improvement works constructed by private individuals or public bodies without the consent of such parties. Some of the more important of these provisions are as follows: Nothing in the Public Health Act, 1875, is to be construed to authorise a local authority to interfere with any watercourse in such manner as to injuriously affect the supply of water to any river, canal, dock, harbour, reservoir, or basin, in cases where any body of persons or person would, if the Act had not passed, have been entitled by law to prevent or be relieved against such interference, without the consent in writing in every case of such body of persons or person (s. 327). Section 332 provides that nothing in the Public Health Act shall be construed to "authorise "any local authority to injuriously affect any reservoir, "canal, river, or stream or the feeders thereof, or the "supply quality or fall of water contained in any reservoir, "canal, river, stream, or in the feeders thereof, in cases "where any body of persons or person would, if this Act "had not passed, have been entitled by law to prevent "or be relieved against the injuriously affecting such "reservoir, canal, river, stream, feeders, or such supply, "quality, or fall of water, unless the local authority first "obtain the consent in writing of the body of persons or "person so entitled as aforesaid."

91. Having dealt with the restrictions imposed by the Public Health Act of 1875, would you proceed to discuss the effect of the Rivers Pollution Prevention Acts?—The series of restrictions to be found in that portion of the Rivers Pollution Prevention Acts which relates to sewage pollution affects the action of local authorities as well as that of other persons. The general rule which the Rivers Pollution Prevention Acts are intended to enforce, may, in the language of Section 3 of the Act of 1876, be stated as follows:—Every person (that is to say, not only every individual but every body of persons whether corporate or unincorporate) who causes to fall or flow, or knowingly permits to fall or flow, or to be carried into any stream, any solid or liquid sewage matter shall be deemed to

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have committed an offence. This rule is subject to conditions which may be classified as (1) designed to relieve the offender, and (2) designed to fix the responsibility of the sanitary authority in certain circumstances. The conditions of the first class may be thus summarised:—(*a*) Where sewage matters falls or flows, or is carried into any stream along a channel used, constructed, or in process of construction for conveying sewage matter at the date of the passing of the Act of 1876—that is, on the 15th of August, 1876—the person, whether an individual or a corporate or unincorporate body, causing or knowingly permitting the sewage matter so to flow or fall, or to be carried, shall not be deemed to have committed an offence if he shows to the satisfaction of the Court having cognisance of the case that he is using the best practicable and available means to render harmless the sewage matter so falling or flowing or carried into the stream. (*b*) Where the Local Government Board are satisfied, after local inquiry, that further time ought to be granted to a sanitary authority which at the date of the passing of the Act of 1876 was discharging sewage matter into any stream or permitting it to be so discharged by any such channel as aforesaid for the purpose of enabling such authority to adopt the best practicable and available means for rendering harmless such sewage matter, the Local Government Board may by order declare that this section (that is, Section 3 of the Rivers Pollution Prevention Act, 1876) shall not, so far as regards the discharge of sewage matter by such channel, be in operation until the expiration of a period to be limited in the Order, which Order may be renewed from time to time subject to such conditions, if any, as the Board may see fit. (*c*) A person (including a body whether corporate or unincorporate) shall not be guilty of an offence in respect of the passing of sewage matter into a stream along a drain communicating with any sewer belonging to, or under the control of a sanitary authority, provided he has the sanction of the sanitary authority for so doing. The condition of the second class, which I have described as designed to fix the responsibility of the sanitary authority, is to be found in Section 1 of the Rivers Pollution Prevention Act, 1893. That section is as follows: "Where any sewage matter falls or flows, "or is carried into any stream after passing through or "along a channel which is vested in a sanitary authority, "the sanitary authority shall for the purposes of Section "three of the Rivers Pollution Prevention Act, 1876, be "deemed to knowingly permit the sewage matter so to "fall, flow, or be carried."

91*. What is your next point in your summary of the law relating to river pollution?—In the foregoing statements we have the substance of the general law respecting the prevention of river pollution by sewage matter. The next point to be noticed is the administration of this law. In the first place, it may be observed that proceedings may be instituted in respect of an offence of this description by any person aggrieved by the commission of such offence. Secondly, every sanitary authority may enforce the law in relation to any stream being within or passing through or by any part of their district. They may institute proceedings against any other sanitary authority or person whether such offence is committed within or without the district of the first-named sanitary authority (s. 8 of the Act of 1876). Thirdly, the Lee Conservancy Board, besides exercising special powers conferred by the Rivers Pollution Prevention Act, 1876, for enforcing provisions of the Lee Conservancy Act, 1868, have within the area of their jurisdiction, to the exclusion of any other authority, the powers of a sanitary authority for enforcing the provisions of the Rivers Pollution Prevention Acts (Section 9 of the Act of 1876). Fourthly, a County Council in addition to any other authority may enforce the law in relation to so much of any stream as is situated within or passes through, or by any part of their county, and for that purpose have the powers and duties of a sanitary authority or other authority empowered to enforce the provisions of the Acts. Fifthly, a Joint Committee or other body representing all the Administrative Counties through, or by which a river or any specified portion of a river or any tributary thereof passes, may be constituted by the Local Government Board by Provisional Order, and this Order may confer on the Committee or body all of the powers of a Sanitary Authority under the Rivers Pollution Prevention Acts, or such of those powers as may be specified in the Order (Section 14 of the Local Government Act of 1888).

92. Now, what have you to say respecting the proceedings for enforcing the law against river pollution?—With regard to the nature of the legal proceedings to be taken for enforcing the Rivers Pollution Prevention Acts as respects sewage pollution, it may in the first place be noted that such proceedings may not in any case be taken until the expiration of two months after written notice to the offender, nor may they be taken while other proceedings in relation to the same offence are pending (Section 13 of the Act of 1876). Next, it may be observed that the Court having jurisdiction in the matter is the County Court; that, to aid the Court in its decisions, it has authority to remit to skilled parties to report on the best practicable and available means for rendering sewage matter harmless, and the nature and cost of the works and apparatus required; and that these experts are in all cases to take into consideration the reasonableness of the expense involved in their report. The jurisdiction of the Court is exercisable by summary order. This order may require abstention from the commission of an offence or may require the performance of a statutory duty. The order may contain conditions as to time or mode of action. It may be suspended or rescinded on such undertaking being given or condition being performed as the Court may think just, and the Court may give such directions for carrying into effect any order as to the Court seems meet. Default is punishable by a penalty not exceeding £50 a day, and enforceable as in the case of a debt. In case of persistent disobedience a person may be appointed to carry the order into effect (Section 10). Parties aggrieved by the decision of the County Court in point of law, or on the merits, or in respect of the admission or rejection of evidence may appeal to the High Court (Section 11). Further in relation to legal proceedings the provisions of Section 12 of the Rivers Pollution Prevention Act, 1876, require special mention. Under that enactment a certificate granted by an Inspector of proper qualifications appointed by the Local Government Board to the effect that the means used for rendering harmless any sewage matter are the best or only practicable and available means under the circumstances of the particular case is in all courts and proceedings to be conclusive evidence of the fact. The certificate is to continue in force for a period to be named therein not exceeding two years, and may be renewed. A party aggrieved by the grant or withholding of a certificate may appeal to the Board, who may either confirm, reverse or modify the Inspector's decision.

92*. Have you any other point before we pass from the discussion of the law relating to sewage pollution?—The definition of the word "Stream," as used in the Rivers Pollution Prevention Acts should be noticed. The effect of Section 20 of the Act of 1876 is that the expression includes rivers, streams, canals, lakes, and watercourses, other than watercourses at the passing of the Act mainly used as sewers and emptying directly into the sea, or tidal waters. But there may also be included the sea to such extent and tidal waters to such point as may, after local inquiry and on sanitary grounds be determined by the Local Government Board by order published in the "London Gazette."

93. Would you now state the effect of the statute law for the prevention of river pollution by manufacturing refuse?—Much of the preceding statement of the law with respect to the prevention of sewage pollution applies to the prevention of manufacturing pollution. The main point of difference in the treatment of the two subjects is the special restriction upon proceedings against alleged offenders of the manufacturing type. For the description of the offence with which the Rivers Pollution Prevention Acts are concerned reference may be made to Section 4 of the Act of 1876. From that it appears that every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream any poisonous, noxious, or polluting liquid proceeding from any factory or manufacturing process shall be deemed to have committed an offence against the Act. Upon lines somewhat similar to those followed in the enactment against sewage pollution the section proceeds thus:—"Where any such "poisonous, noxious, or polluting liquid as aforesaid falls "or flows or is carried into any stream along a channel "used, constructed, or in process of construction at the "date of the passing of this Act, or any new channel "constructed in substitution thereof, and having its out-"fall at the same spot, for the purpose of conveying such "liquid, the person causing or knowingly permitting the "poisonous, noxious, or polluting liquid, so to fall or flow "or to be carried shall not be deemed to have committed "an offence against this Act if he shows to the satisfac-"tion of the Court having cognisance of the case that he "is using the best practicable and reasonably available "means to render harmless the poisonous, noxious, or

"polluting liquid so falling or flowing or carried into the "stream."

94. Have you anything to say about the restrictions upon proceedings against offenders where manufacturing pollution is in question?—The restrictive provisions which control proceedings for offences against this part of the Rivers Pollution Prevention Act, 1876, may be classified (1) as affecting the local authority, and (2) as affecting the central authority.

95. Would you state, first, please, the effect of the restrictions on the local authority?—The provisions under the first head may be summarised as follows:—(1) Proceedings may be taken only by a sanitary authority; and a sanitary authority must first obtain the consent of the Local Government Board. But, if the sanitary authority, on the application of an interested person alleging an offence, refuse to take proceedings or to apply for the necessary consent, the interested person may apply to the Local Government Board. In that case, if the Local Government Board, on inquiry, are of opinion that the sanitary authority should take proceedings the Board may direct the sanitary authority accordingly, who must thereupon commence proceedings. (2) A further restriction upon the action of the sanitary authority may be imposed at the instance of the alleged offender. Notwithstanding any consent of the Local Government Board he may object before the sanitary authority to the proceedings being taken. The authority, if required by him in writing, must afford him an opportunity of being heard. Thereupon the authority must allow him to be heard by himself, agents, and witnesses. After inquiry the authority must determine, having regard to all the considerations to which the Local Government Board (as will hereafter be seen) are directed to have regard, whether such proceedings shall or shall not be taken. (3) Where a sanitary authority has taken proceedings, it shall not be competent to other sanitary authorities to take proceedings till the party against whom the proceedings are intended has failed in reasonable time to carry out the order of a competent Court.

96. Would you next state the restrictions that affect the Central Authority?—Restrictions applicable to the Central Authority are the following:—(1) The Local Government Board in giving or withholding their consent to proceedings must have regard to the industrial interests involved in the case and to the circumstances and requirements of the locality; (2) the Local Government Board must not give their consent to proceedings by the sanitary authority of any district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the poisonous, noxious, or polluting liquids proceeding from the processes of such manufactures are reasonably practicable and available under all the circumstances of the case, and that no material injury will be inflicted by such proceedings on the interests of such industry.

97. Are there any further statutory provisions deserving of notice with regard to refuse from manufacturing processes?—Lastly, under the heads of Manufacturing Pollutions and Administration of Law it may be desirable to draw special attention to an important provision with respect to facilities for the drainage of liquids from manufacturing processes. This is contained in Section 7 of the Rivers Pollution Prevention Act, 1876, which is in the following terms: Every Sanitary or other Local Authority "having sewers under their control shall give facilities for "enabling manufacturers within their district to carry the "liquids proceeding from their factories or manufacturing "processes into such sewers. Provided that this section "shall not extend to compel any Sanitary or other Local "Authority to admit into their sewers any liquid which "would prejudicially affect such sewers or the disposal "by sale, application to land or otherwise, of the sewage "matter conveyed along such sewers, or which would "from its temperature or otherwise be injurious in a "sanitary point of view. Provided also, that no Sanitary "Authority shall be required to give such facilities as "aforesaid where the sewers of such Authority are only "sufficient for the requirements of their district, nor "where such facilities would interfere with any order of "any Court of competent jurisdiction respecting the "sewage of such Authority." And in connection with these provisoes mention may be made of the prohibitory enactments which the Local Authority may apply to their district by adoption of Part 3 of the Public Health Acts Amendment Act, 1890. In that part is comprised Section 17, of which sub-section (1) is in the following terms,—"Every person who turns or permits to enter into any "sewer of a Local Authority or any drain communicating "therewith (*a*) Any chemical refuse, or (*b*) Any waste "steam, condensing water, heated water or other liquid "(such water or other liquid being of a higher tempera-"ture than one hundred and ten degrees of Fahrenheit), "which, either alone or in combination with the sewage, "causes a nuisance or is dangerous or injurious to health, "shall be liable to a penalty not exceeding ten pounds, "and to a daily penalty not exceeding five pounds." Also, as a provision relating to chemical refuse, Section 5 of the Alkali, Etc., Works Regulation Act, 1881 (44 and 45 Vict. c. 37) may be noticed. This enactment requires every work in which acid is produced or used to be carried on in such a manner that the acid shall not come in contact with alkali waste or with drainage therefrom so as to cause a nuisance. The section further provides as follows:—"On the request of the owner of any such "work . . . . the Sanitary Authority . . . . "shall at the expense of such owner provide and main-"tain a drain or channel for carrying off the acid produced "in such work into the sea or into any river or water-"course into which such acid can be carried without "contravention of the Rivers Pollution Prevention Act, "1876, and the Sanitary Authority shall for the purpose "of providing any such drain or channel have the like "powers as they have for providing sewers whether with-"in or without their district under the Public Health "Act. Compensation shall be made to any person for "any damage sustained by him by reason of the exercise "by a Sanitary Authority of the powers conferred by "this section, and such compensation shall be deemed "part of the expenses to be paid by the owner making "the request to the Sanitary Authority under this section."

98. There has been recent litigation arising out of an attempt by a manufacturer to compel the Local Authority to admit liquid refuse into their sewers?—Yes.

99. Will you kindly tell me what that case was?—Yes. The case is that of Peebles *v.* the Oswaldtwistle Urban District Council.

100. And it was carried to the House of Lords, was it not?—Yes.

101. Can you give us a brief account of the proceedings?—Peebles, a paper maker, the owner and occupier of a factory, and, subsequently to his death, his executors and a company to whom the business had been sold, claimed in an action against the Oswaldtwistle Local Board a mandamus to compel the Local Board (1) to cause to be made such sewers as might be necessary for effectually draining their district for the purpose of the Public Health Act, 1875, and (2) to give facilities for enabling the plaintiff to carry liquid from his factories or manufacturing processes into the sewers under their control. As to the first point, it was contended, on behalf of the defendants, that no such writ could be granted because the remedy (if any) is a complaint to the Local Government Board in pursuance of Section 299 of the Public Health Act, 1875. As to the second point the contention was that the remedy (if any) was by procedure under Section 10 of the Rivers Pollution Prevention Act, 1876. Mr. Justice Charles in the Queen's Bench Division took the view that the owner or occupier of a factory was entitled under Section 21 of the Public Health Act, 1875, to connect his premises by a drain with a sewer of the local authority, and to use the drain to its utmost capacity by passing into it liquids of all kinds, not being liquids injurious to health. He also held that Section 299 did not apply, and that the plaintiffs were entitled to a mandamus. On the other point arising out of Section 7 of the Rivers Pollution Prevention Act, 1876, his judgment was in favour of the defendants, as a sufficient and appropriate remedy had been provided in Section 10, the County Court being thereby constituted the proper tribunal to enforce the performance of the duty. Upon the first point the Urban District Council appealed against the judgment of Mr. Justice Charles. The Court of Appeal gave judgment in favour of the Urban District Council, holding that the case came within the rule that, if a new obligation is imposed by statute, and, in the same statute, a remedy is provided for non-fulfilment of the obligation, that is the only remedy, and that accordingly the remedy by complaint to the Local Government Board under Section 299 was a bar to the application for a mandamus. The decision of the Court of Appeal was affirmed by the House of Lords.

102. Then have you got any commentary to make upon any of these points?—I have not yet had an opportunity of reading a shorthand or revised version of the report of the proceedings in the case before the House of Lords. It would, therefore, be unsafe to make any positive statement as to the effect of the law. But, so far as my present sources of information extend, the position seems to be

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as follows:—A manufacturer who seeks admission for his factory refuse to the sewerage system of a local authority has, on the rejection of his application, two available remedies. These are (1) the remedy under Section 10 of the Rivers Pollution Prevention Act, 1876, to be pursued before the County Court on a claim based upon the provisions of Section 7; and (2) the remedy under Section 299 of the Public Health Act, 1875, to be pursued before the Local Government Board on a complaint based on the alleged default of the local authority in the provision of sufficient sewers. The first remedy would be appropriate to the case of existing sewers *primâ facie* available and sufficient for the reception of the refuse. The second remedy would be appropriate where the facts are assumed to point to the need of works of improvement or additional construction. But in certain circumstances it is conceivable that recourse may be had to the second remedy after the first has failed. In connection with the first remedy and its possible failure by the operation of the provisoes to Section 7 of the Rivers Pollution Act, 1876, two judicial *dicta* are deserving of notice. In a Scottish case the Court of Session took the view that the word "land" in the first proviso meant land generally, so that the refuse to be excluded must be so noxious and of such quality as to render the sewage unfit for sale as manure, and not merely that the refuse must be in quantity too great for the limited area of land in use in a particular case. The second *dictum* is that attributed to the Lord Chancellor in the recent case of Peebles v. Oswaldtwistle. According to this view the protective force of the second proviso may be thus stated; the duty lies primarily on the manufacturer to get rid of his own refuse, and it would be unreasonable to permit a man to come to a small district and to require the local authority to reconstruct its system for his purposes.

103. As regards the subject for our investigation, are there any considerations, in your opinion, which lessen the value of these decisions for the purposes of our Commission?—I do not regard the decision in Peebles v. Oswaldtwistle as tending in any way to minimise any difficulties which the Commission may encounter in dealing with that part of the reference which relates to manufacturing refuse. The case, it will be observed, originated in circumstances which differ from those of many cases which will have to be considered by the Commission. The case was one of refusal by the Local Authority to admit the refuse. But the instances in which Local Authorities have admitted or will admit such refuse are, and are likely to be, I think, much the more numerous. At the same time, it seems to me that the case, especially if the *dictum* attributed to the Lord Chancellor should be found in its revised version to be as weighty as may be inferred from the first report, may emphasize the need of a special consideration of the treatment appropriate to each kind of refuse.

104. Lastly, one or two questions as to the practice of the Local Government Board in dealing with schemes of sewage disposal, have you anything to say about their early procedure?—When the Local Government Board came into existence, one of the most important methods of sewage treatment, viz., intermittent downward filtration, was as yet a novelty. The other method of land treatment, viz., by broad irrigation, seems to have been favoured as much as possible when circumstances admitted. But at that time, and, indeed, for some years afterwards, schemes relying upon the efficacy of chemical treatment appear to have been frequently accepted. According to a return made by Parliament in 1873, local authorities who up to that date had provided works of sewage disposal by means of loans numbered in all 128. Of these forty-four had sewage farms, fifty-four had adopted artificial filtration, thirty had precipitation schemes. It would have been difficult for the newly-constituted Department in the then state of the law to take any different course. The Department had before it the results of many years' work of the local and central authorities under varying states of the law. It was impossible to disregard these results to such an extent as to necessitate the entire remodelling of particular schemes upon applications for loans for their enlargement or improvement. And although the Department was fully alive to the need of more stringent legislation for the protection of water courses from sewage pollution, its earlier efforts to promote such legislation were not successful.

105. Can you give any instances of this want of success in securing legislation of the kind mentioned?—In the Public Health Bill, 1872, under the head of "Nuisances," it was proposed by provisions much in advance of any previous enactments to prohibit the pollution of streams or interference with their due flow by solid refuse (Clause 32). It was further proposed (Clause 33) that every person who caused to fall or flow, or knowingly permitted to fall or flow, or to be carried into any stream any solid or liquid sewage matter, or who caused to fall or flow, or knowingly permitted to fall or flow, or to be carried into any stream any filthy or noxious water, or washings of manufactories or other polluting liquid should be deemed guilty of creating a nuisance punishable summarily. The stringency of these provisions, however, would have been subject to relaxation by the proposal to allow a period of two years' grace in the case of the continuance of an existing nuisance. There was a proposal in the Bill (Clause 63) that it should be the duty of every sanitary authority to cause to be analysed in conformity with any directions issued by the Local Government Board any sewage matter, or filthy or noxious water or washings of manufactories or other polluting liquid falling or flowing into any stream within its district. None of these provisions, however, proved acceptable to Parliament.

106. The position, however, was altered rather by the Rivers Pollution Prevention Act of 1876, was it not?—Yes. On the passing of the Rivers Pollution Prevention Act, 1876, the Board found themselves in a position to insist more uniformly upon the observance of special requirements, which generally included land treatment for obviating infringement of the Act.

107. To what period would you assign the beginning of the present practice of the Board?—The present practice of the Board, I think, dates from the investigation of the complaints which led to the appointment of the Metropolitan Sewage Commission. Since the publication of the Report of that Commission the Board have regarded themselves as justified, save in exceptional cases, in requiring that any scheme of sewage disposal for which money is to be borrowed with their sanction should provide for the application of the sewage or effluent to an adequate area of suitable land before its discharge into a stream. At the same time, the Board have been fully prepared to recognise improvements in chemical treatment; and this is shown in the rules which, after much consideration, were adopted in 1890.

108. Can you state the effect of the rules to which you have referred?—These rules may be stated as follows:—For treatment by broad irrigation only:—Land in the proportion of not less than one acre to every 300 of the population must be provided. For treatment by intermittent downward filtration only:—There must be not less than one acre to every 1,000 persons. For broad irrigation in combination with chemical treatment:—There must be not less than one acre to every 1,000 persons. For intermittent downward filtration in combination with chemical treatment:—There must be not less than one acre for every 2,000 persons. It should, however, be stated with regard to these rules that their application is subject to special consideration of the actual circumstances of each case. The Board do not look upon themselves as tied to a uniform and strict observance of the scale. Cost, character of land, and probable increase or decrease of population, among other circumstances, have to be recognised as grounds of exception.

109. Well, I think that ends my examination in chief. The only thing I have got to do, which I am sure I may do, on behalf of the Commission, is to return our most hearty thanks to you for your most able and valuable contribution. I think the information is wonderfully well prepared, and, I am sure, it forms a most excellent start for our Commission?—I am afraid the details have been very wearisome.

110. Not at all; it is so wonderfully clear and terse; I think it is admirable. I am afraid we have tired you pretty well?—I fear I have been an infliction.

111. (*Mr. Killick.*) I should like to ask Mr. Adrian a question or two, if I may. You have not mentioned one or two special Acts which have been obtained—the Mersey and Irwell and the West Riding?—Quite so; I omitted those because, of course, they are local in their effect.

112. But some of their provisions differ rather from the general Acts?—Very materially as regards the administration of the law. The offences of the Mersey and Irwell Act and the offences of the Rivers Pollution Prevention Act are couched in very much the same language, but, of course, the machinery is very different.

113. With regard to the offences. In the Mersey and Irwell Act the offence of pollution by solids, I think the clause in the 1876 Act, the prevention of the due flow of the stream, is omitted?—The clause relating to solid

matters in the Rivers Pollution Prevention Act does not seem to concern the Commission. In the Mersey and Irwell Act so much of Clause 3 of the Rivers Pollution Prevention Act (which, of course, does concern the Commission), so much of that section as relates to solid sewage matter is grouped in the earlier Section (2), relating to obstruction.

114. Sewage might be solid?—Quite so; it is grouped in your Local Act in the clause as to solid matters; it is a little differently arranged.

115. You have not the prevention of the due flow in the Mersey and Irwell Act?—No, Section 2 of the Rivers Pollution Prevention Act hardly concerns this Commission; it is not pollution; it is obstruction.

116. You referred to the 1868 Royal Commission on Sewage and the 1882 Royal Commission on Sewage in the Thames. Those are the two most important Commissions and the two most important reports are they not?—There is also the Sewage Commission of 1857, and, of course, there are the House of Commons Select Committees' reports of 1862 and 1864.

117. The 1868 Commission in their first report gave standards, which they subsequently modified?—You are thinking of the Rivers Pollution, not of the Sewage Commission.

118. 1868?—Yes, the Rivers Pollution Commissioners were appointed originally in 1868; they set out the revised standards in their fourth report, which was published in 1872.

119. In their fourth report; that is so. Those standards have never been adopted in any Act of Parliament?—They were rejected.

120. They were rejected?—They were submitted and rejected in 1872 and 1873.

121. Under the Act of 1876 for the prevention of pollution it is necessary, I think, to prove that the pollution occurs within the district of a Sanitary Authority bringing the action?—Well, yes, that its effect occurs, that is, that pollution is caused within the district.

122. Within the district?—Quite so.

123. In practice it has been demonstrated, I think, that the recommendation of this 1868 Commission, that a watershed must be dealt with as a whole, is a perfectly sound one?—I suppose one ought to say that the question may be debatable, because Parliament, when legislation was attempted, refused to listen to it.

124. It is permissive legislation only?—Permissive—oh, but there was also an idea at one time, following upon the recommendations of the Commission, that Conservancy Boards were quite the one thing needful. Bills for the formation of such Boards were introduced in session after session of Parliament, but without effect.

125. But there is a permissive Act now, the Act which you cited of 1888, Section 14, Sub-section 3, giving county councils in a watershed power to combine to enforce the 1876 Act?—By combination, yes.

126. That is permissive?—By combination, yes, but the uniform definition of the limits of jurisdiction as co-extensive with a watershed is hardly within the practical possibilities of that Section 14.

127. No, but still it would probably be the county councils in a watershed that would combine?—Yes, it might be; oh, yes.

128. I do not know if I am right in asking your opinion as to whether the only way to effectually deal with river pollution is to deal with it in combination?—I think I should go so far as to say that those combinations which have been set up have been successful, but the difficulty of setting up a combination is serious. We have had other instances than those which are in successful working order—instances of attempts, which have been frustrated by local hostility.

129. Then, if it is the most effectual means of dealing with the pollution of rivers, would it not be a desirable thing that instead of being permissive, it should be compulsory upon the County Councils to form joint committees?—I think that is rather beyond our province.

130. The Chairman ruled the other day that all matters in connection with sewage disposal were within our province?—I rather mean when I say that it is beyond our province that, as propositions somewhat of that description have been submitted to Parliament in the past, and have met with almost invariable rejection, I do not know that it is worth our consideration.

131. But, still, the practical experience that you have, of course, is greater than all the other practical experience together. The practical experience that we have had on the Mersey and Irwell and on the attempted joint committee on the Dee all goes to the same point, and I thought possibly you could express an opinion?—But you have not set up a joint committee on the Dee yet.

132. We are only waiting for you to do it?—Has it got as far as that? I was not aware of the later stages.

133. We are prepared to accept your decision?—I was not aware that the case was eventuating in anything like a practical result.

134. Would it be possible for you to let us have a *precis* of the parts of the reports of the 1868 and the 1882 Commissioners which you think are material to our inquiry?—I should rather prefer that the Commission should address any request of that kind to the Board officially. There are certain considerations that will have to be discussed. I should not like to say off-hand whether we can or whether we cannot.

135. (*Sir R. Thorne Thorne.*) I did not quite understand one of your answers, unless, indeed, it were an answer to a hypothetical question. I think Mr. Killick put that question to you as to the combination of Councils in a watershed in this way, that, if it be the best method then would it not be desirable?—Yes.

136. But have you any opinion as to whether it is the best method?—Hitherto in the combinations that have been set up the Board have rather taken into consideration the fact of what is possible in the way of combination; that is to say, in the way of co-operation amongst various authorities, and not with reference to the actual limits of any particular basin.

137. (*Mr. Killick.*) On that, our plea to the Board and our plea to the public in the case of the Mersey and Irwell was that the combination should cover the watershed?—I know you described the area of jurisdiction as a watershed, and in your case the area much more closely approximated to a watershed, but it did not in the other case.

138. In the Ribble?—No.

139. Did it not in the Ribble?—I think not.

140. Yorkshire and Derbyshire stood out because they said they were so small?—Yes, the area of jurisdiction in the case of the Mersey and Irwell did not extend on the Derbyshire side, and, in the case of the Ribble, on the Yorkshire side, to the limits of the watershed. If I remember rightly, there was an exclusion, or a suggestion for exclusion, in the Southport direction in the Ribble case.

141. I did not know of that?—I should say almost certainly in the West Riding direction the exclusion was still more marked.

142. Do you think that it is possible really to purify a river in any way except by a combination of authorities. Take the case now at Chester. Although the Welsh towns are turning their sewage into the Dee untreated there is no means of proving when the Dee comes within the Cheshire or Chester boundaries that the pollution which reaches there is in the Dee at that time. The same case has arisen in the Yorkshire and Derbyshire schemes falling into the Irwell?—Yes. On the other hand, of course, your question rather pre-supposes that you always find this machinery ready to hand. That you do not. The willingness of the northern county councils is hardly reproduced in our experience in county councils elsewhere.

143. Assuming the willingness, surely it is the best way?—I daresay it would be.

144. (*Colonel Harding.*) I wish to ask Mr. Adrian whether the Local Government Board has any supervision over schemes which have been started by any local authorities for the purification of sewage?—The supervision does not extend, except in occasional circumstances, beyond the revision of the scheme in the first instance, the scheme being one submitted in connection with the proposal to borrow money.

145. Then the scheme being once passed by the Local Government Board the Local Government Board have no further supervision as to the continued effectiveness of the scheme?—The Local Government Board would not exercise any supervision over the execution of the scheme itself. It would only, perhaps, in connection with some later application, find it necessary to see how the works of the earlier proposal had been carried out, but beyond that there is no practice of supervising the works of authorities.

146. Then the — supervising bodies, as far as you

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know, are these River Boards, to which allusion has just been made?—They would supervise to the extent of detecting offences.

147. And they supervise further surely in the direction of seeing that the schemes once put into operation are kept effective, do they not?—So far as river pollution is concerned, no doubt they do.

148. (*Sir Richard Thorne.*) With regard to one question. May I take it that the Local Government Board mainly consider whether the scheme is of such a nature as to justify its being carried out at the cost of a loan the repayment of which will extend over a series of years?—Quite so.

149. They do not take any responsibility beyond that?—None whatever.

150. You have several times divided schemes into profitable and unprofitable. Can you, as the result of your experience, tell the Commission whether there is any one scheme—I do not mean its application in one single instance—but a method of sewage disposal which generally offers anything like a profit?—Ah, well, you restrict me when you put it that way. You raise the question of a possible scheme of a profitable kind. What I can say is that in one of the reports of the Rivers Pollution Prevention Commissioners they set out a series of balance-sheets, all of which show a profit in the case of the adoption by various towns of scheme of irrigation.

151. Of broad irrigation?—Of broad irrigation. The only instance, so far as I know, at the present time, that has recently been put before us, as one with any profitable result is, I think, the Norwich scheme. I do not know of any other.

152. That is a broad irrigation system?—A broad irrigation system.

153. Do you know of any chemical or any other system which professes still to have a margin of profit at the end of the year's operations?—As to that, there was a return in 1894, and from that return it is just possible that one might extract here and there cases of a profit. It was a return on, I think, the motion of Mr. Tomlinson—a return of all towns in which precipitation had been adopted—and there were columns in that return for recording the particulars in cases where some profit was received.

154. And did that profit take account of the interest on the loans?—That I can hardly say. If it would be of any use I could hand that return in to the Commission. It is a return "showing the number of Urban Sanitary Districts and Contributory Places in Rural Sanitary Districts in England and Wales in which systems for treating sewage by precipitation are in operation, and whether in such cases the precipitate is of a saleable value." Here and there spread about the return are various statements from which some opinion as to the profit might be formed.

155. It really comes to this, that apart from one or two statements that have been made such as you have referred to, you do not know any system of which you could say that there is a chance of a profit being made after it has been carried out?—Certainly not.

156. (*Major-General Carey.*) Except in cases of broad irrigation almost, I suppose?—I should think that would be the conclusion of those who have gone into the question of profit in the past, but with the exception of the one instance I have mentioned I do not know that we have ever heard recently of any scheme producing a profit.

157. (*Mr. Killick.*) You mention the streams. Have you any recommendation or strong opinion as to the extension of the streams to cover a wider area—a definition of "streams"?—No, I hardly think it is necessary, because, you see when you want to bring into the operation of the law relating to river pollution waters that at present are excluded, you have the power through the co-operation of the Local Government Board.

158. By a Provisional Order?—An Order simply; an inquiry and an Order. You can bring tidal waters, you can bring the sea into the category of "streams," such waters being, of course, those which, in ordinary circumstances, the present law does not reach.

159. Simply by an Order by the Local Government Board?—After inquiry.

160. After inquiry?—Yes.

SECOND DAY.

Tuesday, 12th July, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

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Mr. A. MURRAY, of the Local Government Board, Scotland, called; and Examined.

160. (*The Chairman.*) You are the Chief Clerk of the Local Government Board in Scotland?—Yes.

161. Have you seen the evidence that Mr. Adrian has given?—Yes, it was sent to me.

162. You have had some experience of the questions concerning sewage and sewage disposal so far as your Board deals with them?—Yes. All such questions coming before the Local Government Board pass through my hands.

163. Could you give us a little information as to the law and practice in Scotland regarding these matters, beginning with a statement of the law? What are the leading statutes in Scotland bearing on the subject?—The leading statutes are the Rivers Pollution Prevention Acts, 1876 and 1893; the Public Health (Scotland) Act, 1897; and the Burgh Police (Scotland) Act, 1892.

164. What have you to say regarding the Rivers Pollution Prevention Acts—do they apply in Scotland as they do in England?—Yes; the provisions apply equally to the two countries. Of course there are some modifications necessary to suit the different institutions in Scotland. For instance, the County Court is represented in Scotland by the Sheriff, and the High Court of Justice by the Court of Session. Then we have in Scotland a provision in the Local Government (Scotland) Act, 1889 (Sec. 55), such as there is in the Local Government Act for England, which enables the County Council to act as the local authority in regard to the administration of the Rivers Pollution Prevention Acts, and which also enables the Secretary for Scotland to combine County Councils or other authorities to act jointly for the purposes of rivers pollution prevention.

165. But we may assume that the effect of the law, so far as the pollution of rivers is concerned, is the same in both countries?—Yes, substantially it is. You will observe, however, that the central authority as regards Scotland is the Secretary for Scotland, not the Local Government Board. He takes the place of the Local Government Board so far as Scotland is concerned; he

appoints the Inspector under the Rivers Pollution Prevention Act, and he carries out all the other duties of the central authority.

166. There is a difference in the administrative bodies, but the law itself is very much the same?—It is substantially the same; I may say precisely the same. Perhaps I should explain as to the executive bodies,—the local authorities. They are on a somewhat different footing in Scotland from England. There are, first, the county authorities, the county councils, and district committees. Almost all the counties are divided into districts, and the district committee are composed of the County Councillors for that portion of the county along with representatives from the Parish Councils. The District Committees act as the local authorities under the Public Health Act and also under the Rivers Pollution Prevention Acts. They are, as it were, a stepping stone between the Parish Councils and the County Councils.

167. Yes?—Then as regards burghs, Scotland is in rather a peculiar position owing to the great number of very small burghs. I have a return here of the numbers of them, and I find that there are eighteen with less than 1,000 inhabitants. Then many have a very small rental. There are some of them whose rental is so small that an assessment of a penny in the £ only produces about £5 or £10, and the result is that those local authorities are very difficult to deal with; they have such small resources that they can do very little.

168. Now coming to the Public Health Act, will you tell us what powers are given as to Sewage Works?—There are similar provisions in Scotland to those in England. The local authorities have the same powers as in England. In the first place, all sewers are vested in the local authority—all public sewers.

169. Yes?—Together with all the sewage works connected with them. The Local Authorities have power to acquire rights to make sewers from private bodies, and they have also power to make sewers within their district, or, if necessary for the purposes of outfall or distribution of sewage, without the district. Then they are bound to keep their sewers so as not to be a nuisance. These provisions will be found in Sect. 103 of the Public Health Act. Perhaps I may quote this passage: "For the purpose of cleansing and emptying them"—that is, the sewers—"the Local Authority may construct and place, "either above or underground, such reservoirs, sluices, "engines, or other works as may be necessary, and may, "subject to the provisions of the Rivers Pollution Prevention Acts. cause such sewers to communicate with and be "emptied into such places as may be fit and necessary "either within their district, or, if necessary for the purposes of outfall or distribution or disposal or treatment of "sewage, without their district, and to cause the sewage "and refuse therefrom to be collected for sale or for any "purpose whatsoever, but so as not to create a nuisance." It is a similar provision to that in England.

170. Are there any provisions as to the utilisation of sewage?—Yes. Perhaps before I leave the question as to the power to make sewers, I should call attention to the fact that in Scotland there are no provisions similar to those in England to which Mr. Adrian referred, as, for instance. Sect. 28 of the Public Health Act in England, which enables a local authority to cause their sewers to connect with the sewers of another local authority; there is no provision of that kind in Scotland. And there is no provision enabling a local authority to do outside of their district whatever they may do within their district such as exists in England. With regard to the utilisation of sewage, there is a provision (Sect. 108) similar to that which exists in England enabling a local authority to contract with any person for the purpose of the supply of sewage subject to the authority of the Local Government Board.

171. Have the local authority power to acquire land for sewage works?—Yes, they did get that—only last year.

172. Last year?—Only last year, in the Public Health Act, 1897. Prior to that they had no power to acquire land for sewage works, and many local authorities were seriously hampered by the want of power.

173. Then I suppose the financial provisions are much the same as in England, that the local authorities have power to borrow subject to approval of the schemes?—Well, there is a very decided difference there, because the local authorities have power to borrow without any approval of the Local Government Board.

174. Without any approval?—Without submitting the scheme to the Local Government Board at all.

175. Oh?—It is a very substantial difference.

176. Yes. Now, do you mean they have power to borrow, to do anything they like? I mean, may they say they will put down any sewage scheme they like, and then borrow as much money as they like for that?—Yes, they are quite free.

177. Quite free?—There are restrictions with regard to borrowing which differ somewhat from the English provisions. Section 139 of the Public Health Act is the section, and it provides that it shall be lawful for the local authority "to borrow for the purpose of acquiring, "making, enlarging, or reconstructing sewers, or for the "purpose of utilising sewage." They can borrow for these purposes subject to the restrictions that the money must be repaid within 30 years—not within 60, as in England. I see with regard to Ireland, in the discussion last week on the Local Government Bill, that they propose to allow 60 years in Ireland also; in Scotland it is 30 years.

178. But then who can enforce the repayment of the money?—The bond holders have a lien over the rates. The money is borrowed on the security of the rates, and the rates are assigned to the creditors, and the creditors could enforce the repayment.

179. They could enforce the payment of the sinking fund—I suppose there is a sinking fund?—They may either have a sinking fund or arrange to repay by annual instalments with interest. The statute does not lay down that there is to be a sinking fund.

180. It does not?—No.

181. Are there any other restrictions imposed by the Act, except the time and the naming of the objects for which the borrowing of the loans is to be made?—With regard to financial matters?

182. Yes.—No. Well, there are restrictions in this way, that they cannot rate beyond a certain sum. There is a maximum rate.

183. So that there are not the same provisions as there are in England?—The provisions as to borrowing are very different, and they have no power to borrow on the security of the sewage works, as in England; the only security they can offer is the rates.

184. Is there any provision for the combination of local authorities for sewage works?—Yes; there is a provision (Sect. 121) whereby any two or more local authorities may with the sanction of the Local Government Board combine "for the purpose of executing or acquiring an interest in "or maintaining any works by this Act or any other Act "authorised in regard to sewerage or drainage that may be "for the benefit of their respective districts." They may combine with the sanction of the Local Government Board. There have not been many cases of combination; they are usually very small, such as a village which is in the boundary of two districts—the two districts combine to provide drainage, or a borough and a suburban district may combine.

185. What power have they to compel the provisions of the law to be carried out?—The power to compel local authorities to carry out the law is different from that in England, but I think it is quite as effective. If a local authority fails to carry out its duty, then any ten ratepayers, or a parish council, or the procurator fiscal of the Sheriff Court of the county—he is the public prosecutor for the county in Scotland—or the Board may give notice to the local authority that they are not performing their duty, and if they do not carry out their duty then any of those persons may apply to the Sheriff to compel the local authority. That is one method. Then the Local Government Board have another method—by going to the Supreme Court to compel a local authority to carry out its duty. But the Local Government Board have no power to carry out the works themselves, and charge the local authorities with the cost. They have no power of that kind.

186. What are the rights of the inhabitants and manufacturers as regards the passing of sewage into the sewer?—They have very full rights in Scotland. Under section 110 of the Public Health Act any owner or occupier of premises within the district of a local authority liable for assessment is entitled to cause his drains to empty into the sewers of the local authority on very easy conditions—he has merely to give notice of his intention and to comply with the regulations—"provided that the sewage so "emptied or discharged into the sewers is not of a nature "to cause damage to the structure of the sewer or by admixture with other sewage therein to cause a nuisance." Then there are similar powers given to persons outside

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the district that they may connect their drains with the drains of the local authority. The section (111) contains a further proviso, however, viz.:—"That such sewer of "the local authority and any works connected therewith "are of sufficient capacity and otherwise suitable for re- "ceiving such additional drainage." It is a similar provision to that which exists in the Rivers Pollution Prevention Act.

187. Is there any obligation on manufacturers to purify their sewage before they discharge it into the sewers?—There is a very important provision in the Public Health Act, which is to this effect (section 116): "The owners or "occupiers of distilleries, manufactories, and other works "shall be compelled where possible to dig, make, and "construct pools or reservoirs within their own ground, or "as near their works as possible, for receiving and de- "positing the refuse of such works so far as offensive or "injurious or dangerous to the health of those living in the "vicinity thereof, or to use the best practicable means for "rendering the same inoffensive or innoxious before dis- "charging it into any river, stream, ditch, sewer, or "other channel." So that the manufacturers can be compelled to render the sewage inoffensive or innoxious before discharging it into any sewer of the local authority.

188. And do you think they do. Is that carried out?—Well, some local authorities, I believe, do take some steps to carry it out, but so far as my knowledge goes it is not carried out. But the power generally exists, and the Local Government Board do advise local authorities that they have the power.

189. In the case of very small premises where there is practically hardly any room to do anything in the way of purifying sewage should you say that local authorities had powers to call on the manufacturer to acquire land or space somehow in order to enable him to deal with it?—I am not sure that it would go so far as that. The procedure would be this, that the local authority would say, "We cannot allow you to discharge this sewage of yours into our sewers; if you cannot comply with the section you must dispose of your sewage in some other way."

190. It would not be a sufficient answer for him to say, "Well, I am doing the best I can"?—You see he is only required to use "the best practicable means for rendering "the same inoffensive or innoxious."

191. It would be a legal point, I suppose. Probably the thing has never been tested?—It has never been tested. A question arose in one case as to whether a local authority was bound to provide sewers which would carry off the manufacturing sewage of the district as well as the household sewage. The Local Government Board was a little puzzled over the question, and they consulted the Law Officers. The advice they gave was to the effect that if a local authority were making new sewers they must provide for all the sewage, including manufacturing sewage, but they were not bound to make new sewers for the purpose of taking over the discharges from new manufactories.

192. Are there any other provisions in the Public Health Act dealing with sewage and sewage disposal you would like to call our attention to?—There are none of any great importance. There is a provision which is of use in small places—a village or a hamlet—where the sewage from the houses is discharged into a ditch or watercourse. The local authority may make a sewer and charge the cost on the owners of all the houses that discharge anything but pure water into it. It has often been taken advantage of in small places, but it is not of any very great importance. But I should like to say that there are no provisions in Scotland similar to those in the English Public Health Act, sec. 17 and secs. 327 and 333. Section 17 is: "Nothing in this Act shall authorise any local authority "to make or use any sewer, drain, or outfall for the purpose "of conveying sewage or filthy water into any natural "stream or watercourse, or into any canal, pond, or lake, "until it is freed from all excrementitious or other foul or "noxious matter." There is no such provision in Scotland.

193. The third statute you have referred to is the Burgh Police Act, 1892. What is the nature and scope of that?—The Burgh Police Act is a very important Act in Scotland. It is really the code of municipal law for Scotland. It is not an adoptive Act; and it is not one of those Acts which they require to incorporate into private Acts. The Act applies to all the burghs except the five largest cities in Scotland, and it deals with all sorts of matters—the formation of new burghs, constitution and election of burgh commissioners, the police force, lighting, scavenging, streets, buildings, sewers, water supply, fire brigades, markets, slaughter-houses, and a multitude of other matters of municipal administration. One important feature of it is that it enables any small populous place, any small community with a population of 700 or upwards, on the application of the inhabitants to be formed into a police burgh. When this happens then the Commissioners of the burgh become the local authority under the Public Health Act, and also under the Rivers Pollution Prevention Acts, and in that way a number of very small burghs have been formed, which create some difficulties in administration.

194. Are the local authorities of the burghs confined to the sanitary provisions of the Burgh Police Act to the exclusion of those of the Public Health Act?—No, the two Acts are rather the one supplementary of the other. Except as regards water supply the burghs are not confined to the Burgh Police Act, but regarding sewers, for instance, they may proceed either under the Burgh Police Act or under the Public Health Act, or they may carry out part of the works under one Act, and another part under the other. But with respect to sewers the main distinction between the two Acts is in regard to the assessment. If the burgh carries out the works under the Burgh Police Act then the cost falls entirely on the owners, whereas if it carry them out under the Public Health Act the assessment falls half on the owner and half on the occupier. Then there is a maximum assessment for sewerage under the Public Health Act, or rather a maximum for water and sewers combined, and there is no limit of assessment under the Burgh Police Act. It is a question of convenience, which determines under which Act they are to proceed.

195. What is the nature of the provisions as to sewers that the Burgh Police Act contains?—They are very similar to those in the Public Health Act. The sewers are vested in the Commissioners, and they have power to acquire rights to make sewers, and they have power to make sewers in their burgh only; they have no power to go beyond. If they require to go beyond for the purpose of outfall or otherwise they must proceed under the Public Health Act. A local authority may thus carry out its sewer works within the burgh under the Burgh Police Act, but in going outside the burgh they would have to proceed under the Public Health Act. Then there are one or two provisions which I should like to call attention to. There is Section 222: "Whenever the Commissioners "shall have caused pipes or other works to be "laid in or along any river, burn, or watercourse "within the burgh for the purpose of intercepting "and conveying away the sewage which would "otherwise flow into and pollute the same, it shall not be "lawful for any person to introduce into any part of such "river, burn, or watercourse, along which such pipes are "laid, any sewage or other offensive matter or thing from "any source." By the same section the Commissioners are required to give facilities for drainage into their pipes so as to secure the immunity of the river from pollution. Then there is a provision (Sec. 223) which prevents any person from throwing rubbish or refuse of any kind into the streams of the burgh, and there is also a provision (Sec. 234) for enabling persons outside to connect their drains with the burgh sewers—not only individuals but local authorities, contiguous local authorities, may connect their sewers with the burgh sewers. There is a further provision which is similar to that to which I have called attention under the Public Health Act with regard to the purification of sewage before it is discharged into the sewers, but it differs somewhat from the provisions in the Public Health Act (Sec. 223): "Any owner "or occupier of distilleries," you will observe that distilleries form an important element in Scotland; the pollution from distilleries is very offensive—"manufactories or "other works who causes or permits any refuse, refuse "water, steam or other substance fitted to interrupt the "free passage of a sewer or to be otherwise injurious there- "to, or to be injurious to the health of persons living in "the vicinity, to enter a public sewer, river, or inland "loch, or public reservoir or dock from any such works "shall be guilty of an offence," and is liable to a penalty of £5. "Such owners and occupiers shall construct pools "or reservoirs as near their works as possible for receiving "and depositing such refuse and other substances. If it "shall be impracticable, in the judgment of the Commis- "sioners, to render such refuse or other substances in- "offensive or innocuous, or to prevent the same from in- "terrupting the free passage of the sewer, or otherwise "injuring the same, it shall be lawful for the Commis- "sioners to prohibit and interdict such owner or occupier "from permitting the same to run into such sewer from his "works aforesaid." Then there is a provision that they shall not be liable to the full extent of the assessment if that occurs.

196. Then I suppose if he was refused leave to run it

into the sewer he would have to dispose of it in some other way?—Yes, he must get rid of it in some way.

197-8. Is there any power given to the Commissioners of the burghs to act jointly in regard to sewage works?—There is no general power under the provisions of the statute, except that they may do so by means of Provisional Order. Under the Public Health Act it is a much simpler procedure, they merely require the sanction of the Local Government Board. But under the Burgh Police Act application to the Secretary for Scotland is necessary.

199. Apart from these three statutes are there any general provisions in force in Scotland which bear on the subject?—There is, of course, that provision in the Alkali Works Regulation Act, under which the owners of any works in which sewage is produced is entitled to call upon the local authority to provide a drain, and the cost is charged to the owner. But in addition to that there is a very important power in Scotland at Common Law, which is understood to be more effective in the way of preventing pollution of rivers than any statutory enactments. The rights of proprietors at Common Law are carefully guarded both by the Rivers Pollution Prevention Act and by the Public Health Act, and it has been a very common experience in Scotland for proprietors to take action at Common Law to prevent the pollution of the water of rivers within their property. Of course, I am not a lawyer; but the Common Law on the subject was thus expressed by Professor Rankine, who is an authority on the subject. He is the Professor of Scots law in Edinburgh University, and his work on the rights of proprietors is the standard book on the subject. "Riparian proprietors are entitled to use the water in "any way they like, as it passes through their property, "subject only to certain conditions. Now, these condi- "tions are, that they shall send down the water to their "neighbours below undiminished in quantity and unim- "paired in quality." There have been numerous actions at law on the part of proprietors against polluters, both against local authorities and against manufacturers, and against other proprietors, and Professor Rankine seems to be of opinion that the Common Law is more effective than the Rivers Pollution Prevention Act. He says:— "The Act referred to"—that is the Rivers Pollution Prevention Act—"expressly saves the old Common Law, "the efficiency of which in putting a stop to the un- "warrantable fouling of streams has in Scotland been "proved over and over again. It remains yet to be "seen whether the new broom will sweep cleaner." This was written in 1879. Again, after describing the provisions of the Rivers Pollution Prevention Act, he says, "It thus appears that the Act is not a very thorough- "going measure; and it is not wonderful that in prac- "tice the old Common Law has been found to be still in "many cases the more available weapon." The usual procedure in such cases, if the matter is taken into Court, is that the pollution is either proved to exist, or it is admitted, and in that case the Court usually appoints an engineer and a chemist, or the one or the other, to prescribe a scheme which shall put an end to the pollution, and the Court requires the polluters to carry out that scheme. There was a case in the burgh of Duns, in Berwickshire. A proprietor raised an action against a local authority and it was in the Courts for a great many years, and an engineer and a Professor of Chemistry acted jointly in deciding what was necessary. The proprietor wanted something more to be done; but the Court always upheld the reports of the experts, and finally the matter was taken out of Court on a joint minute. The power of action at Common Law is, I think, of some importance.

200. Are there any local Acts which deal with the subject?—There are two local Acts that I know of which are of some importance. One of them is the Water of Leith Sewerage and Purification Act—that is the Edinburgh Pollution case. A small river passes through Edinburgh, which was very seriously polluted, chiefly by refuse from paper mills and also by the sewage of Edinburgh and of Leith, and there being no power under the Statute law to deal with the matter, they got a private Act which is important in certain particulars. I think one of those is as to the constitution of the Commission. The Commission consists not only of representatives of the local authorities, but also of representatives of the occupiers of the polluting mills—they are members of the Commission. Then there are very extensive powers. They ran a large sewage down the valley of the river, and they required all existing sewers to connect with it, and to be disjoined from any connection with the river, and they required all new sewers to be connected with it. They prevent all sorts of pollution from going into the river, they lay down the rules as to what sort of liquid may be passed from the mills into the river, and not only with regard to what one would call noxious pollution, but also with regard to mere turbidity; they prohibit solid matter, they prohibit all sorts of pollution, and they can lay down the extent to which turbid water is allowed to be passed into the river. Altogether it is a very efficient Act, and it has proved very effective.

201. It has proved very effective?—It has proved very effective. Then the cost is met by an assessment which is levied by the various local authorities, and also an assessment on the occupiers of the mills. They pay a fixed assessment of 2s. 3d. in the £ on the valuation of their mills. Then the other Act, which is the only other local Act I know of in Scotland, is the Glasgow Sewage Act. The Corporation of Glasgow determined to carry out purification works, and they obtained private Acts for the purpose. They are carrying out works at a certain part of the Clyde, and they have powers not only to deal with their own sewage, but with the sewage of the districts through which their main sewer passes on the way to the works.

202. They carry it into the Clyde, do they?—They have purification works, but I understand they are not completed yet. Of course, I only know about this from outside knowledge, because the matter does not come before the Local Government Board. But those are the only two local Acts that I know of.

203. Can you give us any information as to the practice of the Local Government Board in dealing with schemes of sewage disposal?—The Local Government Board have very little to do in the matter. Under the Rivers Pollution Prevention Act, as I have explained, the Secretary for Scotland is the central authority. Of course, there are these schemes of utilisation of sewage which come before the Board for approval; if the contract extends beyond five years the approval of the Board is necessary, but the Board do not go into the merits of these schemes.

204. As I understood, the sanction of the Local Government Board is not necessary for raising the loans at all?—No. The only case in which these schemes come before the Board with regard to loans is when the Local Authority wishes to borrow from the Public Works Loans Commissioners. In those cases the recommendation of the Board is required before the Loans Commissioners will give the money.

205. But in a scheme for dealing with sewage disposal if they are going to borrow money locally on the security of their rates, the Local Government Board need never hear of the scheme or anything about it, need they?—Possibly not; they need not. As a matter of fact, it is only the smaller schemes that come before the Board; the larger Corporations, as a rule, borrow outside; they can borrow privately; but the smaller bodies prefer to go to the Public Works Loan Board, and accordingly their applications come through the Local Government Board, and that constitutes the only practice of the Local Government Board with regard to sewage schemes.

206. Of course, they may require dealing with in the same way as they would in England?—Very much the same way, except that the Board in Scotland have no permanent official of their own: they have no staff to deal with the matter, and they appoint an outsider, generally an engineer in practice, to report on the works. But they do not take any great responsibility with regard to seeing that the sewage works carry out the provisions of the Rivers Pollution Prevention Act; they do not hold themselves responsible for that, although they do go into the matter. The engineer generally reports whether the scheme complies with the existing law or not, and if it does not, the Board declines to recommend.

207. But have they laid down any rules or conditions on which they insist before recommending a loan for sewage works?—No; they have laid down no rule, each case is considered on its merits, and the report of the engineer carries great weight with the Board.

208. But would they insist in Scotland on some land treatment of sewage?—Not necessarily land treatment.

209. And beyond these applications for loans have the Board any means of knowing what action has been taken throughout Scotland in connection with sewage disposal?—Well, there are one or two sources of information. Perhaps the most frequent is complaints by individuals of

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nuisances arising, and some of those are rather important. Recently in the Burgh of Rothes, where there are several distilleries, there was a complaint of the very serious pollution of the river there, and the Board put pressure on the local authority and they have carried out works of precipitation and land filtration. I do not know whether they are very successful yet or not, but in that case the Board declined in the first instance to recommend that the local authority should get a loan because the amount of land they had devoted to the purpose was not sufficient in the opinion of the engineer.

210. But I understand that the Local Government Board do not make an absolute rule that land treatment should form part of the sewage schemes?—No, they have no absolute rule; they have not laid down a rule. Perhaps another source from which the Board have derived quite as much information is the reports of the County Medical Officers and Sanitary Inspectors. Those are expert sanitary officers, and they report yearly to the Local Government Board. Their reports always describe any new schemes of sewage disposal and also refer to any outstanding cases of pollution. In that way the Local Government Board have a fair idea of the action that has been taken in regard to sewage disposal.

211. (*Mr. Killick.*) I should like to ask if manufacturers as a rule treat their sewage in Scotland?—I am afraid not, so far as I am aware.

212. And sanitary authorities—do they as a rule treat their sewage effluent?—Well, speaking as to the practice within recent years, they do.

213. They do?—Within recent years.

214. (*Major-General Carey.*) Can any pressure be brought to bear on a sanitary authority if it is not borrowing money from the Public Works Commissioners for carrying out schemes of sewerage or sewage disposal?—Yes. If the attention of the Local Government Board is called to their failure to carry out the law the Local Government Board put pressure on the local authority, and may possibly take action against them.

215. They do not come to them for approval of the scheme?—No. Where the Local Government Board take action in the Courts against a local authority, then the scheme is carried out, as I explained, under a remit to an engineer, or an engineer and a chemist, and this work has to be done not to the satisfaction of the Local Government Board but to the satisfaction of the Court.

216. (*Mr. Cotton.*) I should like to ask if there is any provision in the Scots Act corresponding to Section 299 of the English Act, under which, if a complaint is laid by anyone that a local authority are in default—not providing sufficient sewerage for their district—the Local Government Board must inquire into it, and if it is proved, must proceed to enforce by mandamus; is there any provision of that kind enabling anyone to make a complaint?—No; there is no provision in the Scots Act authorising any individual to make complaint to the Local Government Board. As a matter of practice they do, but the Local Government Board are not bound to act; they are not obliged to act on the complaint of an individual, but if they are satisfied that the complaint is well founded, and that it is in the public interest for the Board to interfere, they frequently interfere, but if it is merely a nuisance to an individual I should think it very unlikely that they would interfere.

217. And would the interference be in the same way—to get a rule of the Court to compel the local authority to do it?—Yes, that would be the procedure.

218. (*Dr. Russell.*) I think you said that the Rivers Pollution Prevention Act was administered in Scotland under the Secretary for Scotland?—Yes.

219. And not under the Local Government Board. So that you really, as representing the Local Government Board, have no official knowledge of what has been done under the Rivers Pollution Prevention Act in Scotland?—No, that is so. I have really very little official knowledge of what has been done under the Rivers Pollution Prevention Act. The inspector under the Rivers Pollution Prevention Act is the servant of the Secretary for Scotland, and not of the Local Government Board.

220. There is an inspector in Scotland under the Rivers Pollution Prevention Act?—Yes, Mr. Curphey is the Inspector.

221. I think he is also the Inspector under the Alkali [illegible]?—I believe he is.

222. Does he make periodical reports, or make reports to the Secretary for Scotland?—Yes, he makes reports to to the Secretary for Scotland. I saw the other day there was a report of his published—a series of reports.

223. In which he gives an account of the inquiries which he had held at the order of the Secretary for Scotland under the Act?—Yes.

224. And in order to get information as to his work and the result of those inquiries, one would need to refer to those reports?—Yes, those are the only means the Local Government Board has of obtaining that information.

225. And as to the common law of Scotland, you have told us chiefly it was employed with reference to pollution by local authorities?—Well, not chiefly; it has been employed against local authorities, but I cannot say whether chiefly or not. As a matter of fact, the cases are not all reported. In Scotland in the Law Reports cases tried before a jury are not often reported, because they are questions of fact, and the Law Reports contain chiefly cases which deal with questions of law.

226. Is there any source to which we could refer as being likely to get information of such cases—any authorised source, law reports or anything of that sort?—There are, of course, the law reports, the Court of Sessions cases, and then there is Professor Rankine's book, his work on the Law of Landownership in Scotland.

227. Perhaps you know as matter of common knowledge in Scotland that there have been numerous very serious cases dealing with very important industries at common law in certain rivers?—Oh, yes.

228. Such as paraffin oil works?—Yes.

229. And distilleries?—Yes. There was one recently; the Countess of Seafield brought an action against the distilleries on the Spey.

230. Woollen manufactories and paper manufactories?—Yes; paper mills. Some years ago there was a very important case—the Duke of Buccleuch against the papermakers on the Esk. That is perhaps the leading case on the subject, and the law was very fully laid down in that case. It was a case which went on for a long time. The pollution was dealt with under reports from engineers and chemists—chemists chiefly—appointed by the Court.

231. They appoint a chemist or engineer as a referee, and he reports, and according to his report the manufacturer is put under certain restrictions; that is the practical issue, is it not?—Yes, that is really what it comes to. The pollution being admitted, then the Court says that it is to be put an end to, and the procedure they take is to appoint an expert to report as to what is necessary to put an end to the pollution. He reports, but usually the manufacturers are given a reasonable time to carry out the recommendations of the report, and also the Court allows some time to see whether those recommendations are really effective.

232. I think, in fact, they sometimes give an appointment for a continuity, it may be, of years to some authority to act as an inspector over individual works or classes of works?—Yes. I do not know whether the Court appoints the engineer or chemist for a specific number of years, but as a matter of fact the experiments go on for a number of years under the charge of the person to whom it is remitted—the engineer or chemist, as the case may be.

233. So that the practical result of that is with reference to a person engaged in an important industry, that from the accident of being situated upon a river within the sphere of this person who takes the action at common law he may be subjected to restrictions which no other person competing with him is subjected to at all?—Yes. Well, of course, the law is the same for everyone, but it is not every proprietor who seeks to enforce it.

234. Exactly?—Yes.

235. I think as regards the water of Leith you said it was very effective—the results of that Commission?—Yes, that is so.

236. As matter of fact it was practically a common sewer before the Commission was instituted?—Yes, towards the mouth it was really a common sewer.

237. I think it has been stocked with trout now, has it not?—Yes, and there is evidence to the eye of everyone that the means have been quite effectual.

Mr. L. E. H. Deane, Engineering Inspector, Local Government Board for Ireland, called; and Examined. *Mr. L. E. H. Deane.* 12 July 1898.

238. (*Chairman.*) You are one of the Engineering Inspectors of the Local Government Board for Ireland?—Yes.

239. You have seen the evidence given before this Commission by Mr. Adrian?—Yes.

240. The provisions of the Public Health (Ireland) Act, 1878, are very nearly identical with those of the Public Health Act, 1875?—Yes, read with the amending Public Health (Ireland) Act, 1896.

241. Would you point out any practical differences that exist between what I may call the English and the Irish Acts?—Premising that the expression "local authority" in the English Act is replaced by "sanitary authority" in the Irish Act, I find that Sections 27, 29, 30, and 31 of the English Act relating to "Disposal of Sewage" are identical with Sections 30, 32, 33, and 34 of the Irish Act. Sections 32, 33, and 34 of the English Act, "As to Sewage Works without District," are the same as Sections 35, 36, and 37 of the Irish, with changes as to notices to be served consequent on differences in the constitution of the road authorities in the two countries. Section 16 of the English Act, giving powers to make sewers within or without the district of the local authority is identical with Section 16 of the Irish Act. Section 28 of the English Act, as to the communication of sewers of adjoining local authorities is identical with Section 31 of the Irish Act. Section 285 of the English Act, giving local authorities power to execute works in adjoining districts, and to combine for execution of works had no corresponding section in the Irish Act of 1878, but Section 2 of the Public Health (Ireland) Act, 1896, gives exactly similar powers so far as sewage disposal is concerned. The provisions of the English Act relating to the constitution of united districts under joint boards are contained in Sections 279, 280, 281, 283, and 284, and provisions practically the same are contained in Sections 12, 13, 14, 235, and 236 of the Irish Act, and the procedure is as described by Mr. Adrian in his answer to question 86. The provisions of the English Act relating to "Purchase of Lands" are contained in Section 175, which, as far as sewage disposal is concerned, is the same as Section 202 of the Irish Act, and Section 176 is also practically the same as Section 203 of the Irish Act of 1878; but the procedure under it has been greatly modified by Section 8 of the Public Health (Ireland) Act, 1896, which enacts that "the provisions of the Lands Clauses Acts with respect to the purchase and taking of lands otherwise than by agreement, shall be deemed to be amended by the provisions contained in the Second Schedule of the Housing of the Working Classes Act, 1890, and such provisions shall (subject as by this Section provided) be deemed to form part of the principal Acts as if therein expressly enacted." This provision has greatly simplified the proceedings to put in force powers of compulsory purchase under the Public Health Acts in Ireland. (1) On the application of the sanitary authority the Local Government Board appoints an arbitrator. (2) The arbitrator having received the claims, and having heard all parties interested, makes his award as to compensation and accommodation works. (3) Such award is final, and cannot be appealed from except where more than £1,000 is awarded to any one party, and then only with the consent of the High Court. The proceedings are thus very much shortened, and the trouble and cost of appeals to juries are avoided. Section 177, which is the same as Section 204 of the Irish Act. Section 234 of the English Act as to the exercise of borrowing powers, and Section 235, as to borrowing on credit of sewage land and plant, are the same as Sections 238 and 239 of the Irish Act. Sections 51, 69, 305, 306, 307 and 308 of the English Act, which deal with minor matters auxiliary to a scheme of sewage disposal, are identical with Sections 61, 78, 271, 272, 273 and 274 of the Irish Act respectively. Sections 17 and 327 to 333 of the English Act, containing restrictions, are identical with Sections 19 and 281 to 287 of the Irish Act. Those are the differences.

242. Have you any remarks to make as to the application of the Rivers Pollution Prevention Act to Ireland?—As regards the Rivers Pollution Prevention Act, 1876, the evidence of Mr. Adrian, except, of course, when he referred to the Lea Conservancy Board and County Councils, fully applies to Ireland.

243. Have you anything to say as to the practice of the Local Government Board for Ireland in dealing with schemes of sewage disposal?—The Local Government Board for Ireland will not sanction a loan for any scheme contravening the provisions of the Rivers Pollution Prevention Acts. Owing, probably, to the fact that the principal towns in Ireland are situated near the sea, and on tideways, very few schemes for special sewage disposal have been proposed or approved of. Recently two of the larger inland towns have proposed treatment on the septic system, and the Board have intimated that no application for loans for this purpose will be entertained except land for irrigation, before discharge into a stream is provided at the rate of one acre for every two thousand inhabitants, and steps have been taken to acquire sufficient land accordingly in each case.

244. Does the Local Government Board for Ireland exercise any supervision over schemes for sanitary works?—Not over the execution of the works. When Government loans for sanitary purposes are granted, *i.e.*, loans advanced by the Commissioners of Public Works in Ireland, acting with the consent of the Treasury, the loans are advanced in instalments, as may be from time to time recommended by the Local Government Board, who satisfy themselves that the previous instalments have been expended on the works for which the loans were sanctioned, without, however, accepting any responsibility as to the way in which the works have been executed, for which the sole responsibility rests with the professional advisers of the sanitary authorities. When works have been completed under Government loans, no further supervision is exercised by the Local Government Board for Ireland. Ninety per cent. of the loans borrowed for sanitary works in Ireland are advanced by the Commissioners of Public Works in Ireland acting for the Treasury.

245. Have any proceedings been taken under the Rivers Pollution Prevention Acts in Ireland?—None that I am aware of.

246. (*Colonel Harding.*) I merely want to ask if I may. You say that in Ireland very little progress has been made in connection with sewage treatment on account of the cities being mainly in the littoral?—Exactly.

247. And in the way of the treatment of trade effluents very little has also been done?—Very little has been done.

248. Can you tell us in the cases where anything has been done, what has been the system generally adopted?—Nothing has been done as yet, but in two cases—Armagh and Lisburn, the septic system has been proposed.

249. Proposed only?—Yes, proposed, not carried out. There may have been some small loans, I cannot recollect.

250. In the case, for instance, of Belfast, is nothing done for the treatment of sewage, or is it carried out to sea?—That is tidal. It is carried out to sea.

251. It is discharged untreated into the tidal?—Yes.

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252. (*Chairman.*) We are very much obliged to you for taking so much trouble to put your evidence in such a very convenient form. You are the Chief Inspector to the Mersey and Irwell Joint Committee?—Yes, I am.

253. And you were appointed to the position in November, 1891?—That is so.

254. Now the first question would be to describe the origin and formation of the Joint Committee?—The formation of the Joint Committee was the outcome of a very general feeling in Lancashire and Cheshire that the polluted condition of the rivers Mersey and Irwell was a disgrace and a nuisance, and that little was likely to be done for the improvement of these rivers under the then existing means for enforcing the Rivers Pollution Prevention Act. This Act had been in force since 1876, but it was practically a dead letter. It was very difficult for an Authority to bring proof of pollution within its own area against pollutors outside that area, and an Authority was unwilling to purify its own effluents whilst others on the stream did nothing. The construction of the Manchester Ship Canal, in which the waters of the River Irwell are impounded for several days or even weeks in dry weather, made the improvement of the rivers a matter of urgency. On the 23rd of August, 1889, a conference of Sanitary Authorities in the watershed of the Mersey and Irwell was held in the Town Hall, Manchester, and presided over by Lord Egerton of Tatton. At that meeting the following resolutions were agreed to: —(1) That the County Councils of Lancashire and Che-

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shire and of the County Boroughs therein be respectfully requested to exercise the powers conferred upon them under Section 14 of the Local Government Act, 1888, to compel all Authorities whose sewage passes into the rivers Mersey and Irwell and their tributaries to take immediate measures for complying with the provisions of the Rivers Pollution Prevention Act. (2) That the County Councils of Lancashire and Cheshire and the Councils of the County Boroughs in the watersheds of the Mersey and Irwell be invited to appoint representatives to this Committee. (3) That the attention of this Committee having been called to complaints arising from the condition of the water of the River Medlock, this Committee respectfully requests all Authorities whose sewage passes into that river to take immediate measures for complying with the Rivers Pollution Prevention Act, as the period has arrived when it is necessary that legal action be taken to enforce that Act. These resolutions were sent to the County Councils of Lancashire and Cheshire, which bodies decided to apply to the Local Government Board under the 14th section of the Local Government Act, 1888. In July, 1890, a second conference was held in Manchester of representatives of the County Councils of Lancashire and Cheshire and of the different County Boroughs within the watershed. At that conference, which was presided over by Sir J. T. Hibbert (then Mr. Hibbert), it was unanimously decided to support the application to the Local Government Board, and a basis of representation and payment of expenses, was agreed upon. As the result of the application to the Local Government Board, a local inquiry was held by Col. Ducat and Dr. Thompson, at Manchester, in December, 1890, which was attended by representatives of the different counties, county boroughs, and other Authorities within the area, and also by representatives of the manufacturers. The manufacturers strongly supported the application, and their views were expressed in the following words, quoted by Sir John Hibbert at that inquiry:—"The manufacturers say that without co-operation between the different bodies and the manufacturers no real improvement would be effected in the rivers. They also submit that individual cases ought not to be taken indiscriminately, or dealt with separately, without some assurance being given that others in the district, in competition would be treated on the same principle." The outcome of this inquiry was that a Provisional Order was issued by the Local Government Board, dated the 8th day of May, 1891, which was confirmed by the Local Government Board's Provisional Orders Confirmation (No. 10) Act 1891, constituting the Joint Committee of the Rivers Mersey and Irwell. A further order was subsequently issued to comply with Article IX. of the previous Order, fixing the place and time at which the first meeting of the Joint Committee was held.

255. Will you state the constitution of the Joint Committee?—The representation on the Joint Committee was, by the Provisional Order, fixed as follows:—Lancashire County Council, 8 members; Cheshire County Council, 3; County Borough of Bolton, 1; County Borough of Bury, 1; County Borough of Manchester, 6; County Borough of Oldham, 1; County Borough of Rochdale, 1; County Borough of Salford, 2; County Borough of Stockport, 1; total, 24 members. The first meeting was held at the Assize Courts, in Manchester, on the 5th day of October, 1891.

256. Towards what objects was the first work of the Joint Committee directed?—The early efforts of the Joint Committee were directed chiefly towards the prevention of solid pollution, and considerable advance was made; a survey was also made of all the sources of pollution by sewage and manufacturers' waste waters. It was, however, soon found that the Rivers Pollution Prevention Act of 1876 was in many ways unsatisfactory and difficult of application, and it was, therefore, resolved, on the 7th of December, 1891, to apply to Parliament for further powers. The Bill was opposed by certain of the boroughs and local authorities, but was supported by the manufacturers, who from the first expressed the opinion that they would derive great benefit from the rivers being improved, and who have, as a rule, shown great willingness to meet the Committee. The improvement which has already taken place in the rivers—and this is very marked in the upper reaches—is in a large measure due to what has been done by the manufacturers for the treatment of their waste waters, and for the prevention of cinders and solid matter being thrown into the river. The progress made by the Joint Committee is set forth in reports which have from time to time been made. Copies of these reports have been laid before the Commission.

257. Have you considered the question of a Standard of Purity being adopted for Trade Effluents?—The question of adopting standards was considered by the Joint Committee at an early date, and it was decided that no fixed standards should be adopted. This principle has been adhered to, and is embodied in a memorandum dated November 2nd, 1890. There seemed to be strong reasons for this course, the facilities for erecting plant for the treatment of waste waters varying so much with different works. Where works are situated in the country, with plenty of vacant land around, good tanks and filters can be built, and a high standard of excellence attained; but when a works is situated in a town, with no available space beyond a yard, or perhaps a tank under the floor of the works, the difficulties are very much increased. If a standard were fixed low enough for all to attain to it, works fortunately situated would be let off more easily than they should be, and they could not be compelled to do what might reasonably be expected of them. The words of the Act, that "the best practicable and reasonably available means" be used, seemed to create an elastic standard, which is always capable of improvement as experience is gained; in cases of prosecution no difficulty has been experienced at present in showing that the best available means were not being used.

258. Do you think there is any desire on the part of manufacturers to have fixed standards?—The question of adopting standards is from time to time discussed at conferences, etc., and manufacturers have in many cases advocated them, so that one cannot close one's eyes to the fact that they are a possibility of the future, and the Commission may possibly consider the matter. If adopted, they should be stringent enough to be attainable by those works only where efficient plant can be erected. It would be most difficult to raise the standards when once fixed, and they should, therefore, be fixed high, and the Administrative Boards might have power to relax them for a limited period until experience had been gained. If fixed low, the future improvement in the rivers will be limited. The difficulty with regard to works so situated that the attainment of the standard by them is impossible, might be got over by the admission of their waste waters into the sewers. This course should not be advocated, I think, as a general rule, as the admission of trade waste complicates the treatment of the sewage at the outfall works owing to its varying quality and quantity. If admitted into the sewers, it seems fair that the manufacturer should pay a special rate, which will not only go towards the cost of treatment at the outfall works, but will also put him on the same footing as the manufacturer who carries out his own purification works.

259. Has the Joint Committee considered the question of Artificial Filtration being in certain cases sanctioned instead of land?—In October, 1893, it was proposed that a deputation from the Joint Committee should wait upon the Local Government Board to urge that considerable delay was taking place in the progress being made by Local Authorities with their sewage schemes owing to the Board's requirements as to the purchase of land, and I laid the following report on the subject before the Committee:—On the subject of the proposed deputation to the Local Government Board, I would call the attention of the Joint Committee to the following points:—It would be difficult to show any system of sewage treatment equal to that required by the Local Government Board, viz., precipitation in tanks and subsequent land filtration on an area of suitable land, and the Local Government Board have, therefore, good reason for insisting on this system if land can be obtained. There are, however, cases where suitable land cannot be obtained, or only at great cost, and then the Local Government Board might well modify their hard and fast rule. In these cases I think the Board should be willing to pass a less expensive scheme if, after local inquiry it is satisfied that there is a reasonable prospect of the scheme being an efficient one, at the same time throwing all responsibility on the Local Authority if the scheme should subsequently prove inefficient. As to how far this question affects the Authorities in your district, I would point out that, with the exception of two or three cases, all the Authorities have conformed to the Local Government Board's requirements, and that a deputation, even if successful, would not materially forward the object we have in view.

In April, 1897, instructions were given for reports to be prepared as to the efficiency of the results obtained in the treatment of sewage by precipitation and artificial filtration. The following report was presented to the meeting held on May 31st:—

"Manchester, May 26th, 1897.

"To the Consulting Sub-Committee.

"Gentlemen,—In accordance with a resolution of the Committee that a special report be prepared on the results obtained by the treatment of sewage by precipitation and filtration at the various works in the watershed where this method of treatment is adopted, I beg to report as follows:—

"The total number of authorities using this method of treatment represents a population of about 172,000, and the results obtained, as gauged by the analysis of samples taken, are satisfactory in about 86,000, or one-half of the total; this seems a small proportion, but if the matter is looked into it is evident that the filters which have failed have had little chance of success from the outset, either in consequence of the tank effluent which is put on them being insufficiently precipitated, in consequence of the filters being badly constructed or mismanaged, or in consequence of the area being too small to deal with the volume of sewage. One or other of these reasons has, in my opinion, been the cause of failure in every case where precipitation and filtration has been attended with unsatisfactory results.

"The experiments on a considerable scale which have been made by Sir Henry Roscoe at the Manchester works, by Mr. Dibdin in London, and by Mr. Corbett in Salford, clearly demonstrate the possibility of treating the sewage of large towns by artificial filtration if a sufficient area of filter beds be used.

"There seems, therefore, to be ample evidence to show that if filters are constructed to conform with the principles which have been laid down that satisfactory results may be obtained.

"It is, however, necessary not to lose sight of the fact, which would, I think, be supported by high scientific evidence, that if suitable land is obtainable, filtration through land is the most permanent and satisfactory method of treatment. This is fully borne out by the experience on the Mersey and Irwell watershed, where the proportion of works with land treatment giving satisfactory results is considerably higher than those with artificial filtration.

"Failure with land treatment has in several cases taken place, but these failures again are attributable either to the land being unsuitable to the purpose, to its being improperly laid out or badly managed, or to the volume of sewage turned on to it being greater than it can deal with.

"The reasonable view to be taken of the matter seems to be that instead of any hard and fast rule being laid down, each case should be treated on its own merits—that if suitable land can be obtained it should be used; but that if it cannot be got, artificial filters should be sanctioned, but with stringent restrictions as to the volume of sewage allowed on a given area.

"I am, your obedient servant,

"R. A. TATTON."

These reports were considered at a meeting held on July 5th, and it was resolved—"That a copy of the reports of Sir Henry Roscoe and Mr. Tatton upon the question of artificial filtration be forwarded to the Local Government Board, with the request that the same may receive its most careful consideration; and that, in addition, a deputation from this Joint Committee wait upon the Local Government Board with the view of showing the objections to a hard and fast rule being laid down with regard to land filtration."

260. Was a deputation received by the Local Government Board on the subject?—In accordance with this resolution, a deputation waited upon the Local Government Board on July 21st.

261. Has more recent experience altered these views?—More recent experience has in no way altered the conclusions come to 12 months ago, and I would venture to suggest that the requirements of the Local Government Board should be modified, so that in cases where it is proved that suitable land cannot be obtained, filtration may be sanctioned. Land to be suitable for the purpose must be porous, with a gravelly or sandy subsoil, admitting of free drainage; if land of this description *can* be obtained it should be insisted upon, as giving the most satisfactory and economical results. Clay land is unsuitable, not only from the land refusing to pass the required quantity of sewage, but also from the fact that during dry weather cracks form on the surface, which admit the sewage direct into the drains without purification. This has happened in the Mersey and Irwell watershed at Tyldesley, Swinton, and Westhoughton. Other authorities, although they have bought clay land, so as to conform to the requirements of the Local Government Board, do not use it—instances are Gorton and Royton. The requirement of the Local Government Board at the present time is an area of land of 1 acre per 2,000 persons, in addition to tanks and filters—that is, taking 25 gallons per head, 2 inches of water over the whole area in 24 hours: a large quantity for clay land to pass in a wet climate.

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262. Are Manchester and Salford in difficulty as regards the acquisition of land for sewage purposes?—The cases of Manchester and Salford are both peculiarly difficult, as suitable land in sufficient quantity to provide for the united populations, amounting to 735,000 persons, cannot be obtained except by pumping at great cost. Manchester, with a population of 535,000, would require an area of 268 acres to satisfy the requirements of the Local Government Board, whereas Manchester's own experts have advised that, owing to the land which can be obtained being unsuitable for filtration purposes, an area of 1,300 acres would be required. The reports on which this advice is based will no doubt be laid before the Commission by the proper authority. It would seem more advisable in these and similar cases that the Board should sanction schemes including artificial filtration, instead of insisting on land, when the use of it is doomed to failure.

263. Will you describe the systems of artificial filtration?—The systems of artificial filtration may be conveniently divided under two heads, namely:—(1) Those in which organisms perform the function of transforming the organic matter accumulated in the filter; and (2) Those in which the organic matter is periodically washed out of the filter, or the filtering material renewed. The former method (1) has been adopted by Sir Henry Roscoe on an experimental scale at Manchester, by Mr. Dibdin at Sutton, and by the Oldham Corporation and the Swinton Urban District Council in the Mersey and Irwell watershed. The other method (2) has been adopted by many authorities in the watershed, and satisfactory results have been obtained. Particulars as to each case are given in the reports and supplemental reports of the Mersey and Irwell Joint Committee, furnished, and will no doubt be the subject of careful investigation by the Commission.

264. What are the chief causes of failure?—Failure in both these systems, where it occurs, seems to come from the same cause, namely, the accumulation of organic matter in the filter. Under system (1) the sewage must be diverted from the filter, and the filter emptied of its water at intervals, so that air may be admitted into it, and allow the transforming process to take place. These intervals and periods of rest are required every two to four hours, according to circumstances; longer periods of rest are also required at times. Under system (2) the filters are arranged so that each filter in the series can be washed by clarified water being passed into the lower portions of the filter and upwards through the upper and finer beds, the organic matter accumulated in the body of the filter being brought to the surface by the flow of water and brushed away. The periods of time during which filters are allowed to be in operation without being cleansed vary considerably according to the degree of purity of the tank effluent which is turned on to them; in some cases they are allowed to run as long as two days. The quantity of water passed through filters under this system (2) is greater per square yard than under system (1), but great care must be taken with the cleansing process, which should be repeated after each time the filter is used. The cost per square yard is greater and the maintenance is greater under system (2) than under system (1), but the quantity of water dealt with is also greater.

265. What are the chief points of difference between the Rivers Pollution Act of 1876 and the Mersey and Irwell Act of 1892 as regards solid matter?—The chief points of difference between the Pollution Act of 1876 and the Mersey and Irwell Act of 1892 are as follows:—Under the 1892 Act it has been made an offence to put solid matter in such a position as to be liable to fall or be carried into a stream, and it is not necessary to prove that the solid matter interferes with the due flow or pollutes the waters of the stream. The word "sludge" has been introduced. This is a term well known in the North to express matter in a semi-liquid condition, as found in a tank or reservoir in which water containing suspended matter has been stored. It has been a com-

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mon practice to run off these reservoirs into the stream and eject the accumulated sludge, causing serious pollution.

266. As regards pollution from sewage?—The clauses under this portion of the Act are much simplified. The 1892 Act is prohibitive, and the saving clauses regarding channels constructed prior to 1876 have been done away with. Appeal to the Local Government Board on the part of a defaulting authority for time to construct works has been abolished, but somewhat similar powers are given to the Joint Committee.

267. As regards manufacturing pollution?—In the 1892 Act the following words which are in the 1876 Act are omitted: "The said Board" (*i.e.*, the Local Government Board) "in giving or withholding their consent, shall have regard to the industrial interests involved in the case, and to the circumstances and requirements of the locality." Also, "The said Board shall not give their consent to proceedings by the Sanitary Authority of any district which is the seat of any manufacturing industry unless they are satisfied after due inquiry . . . . that no material injury will be inflicted by such proceedings on the interests of such industry." Under the 1892 Act the Joint Committee shall, before taking proceedings, invite the defaulting manufacturer to appear before them and state his case; there is no provision of this kind in the 1876 Act. Under both Acts the consent of the Local Government Board is required before proceedings are taken; but under the 1892 Act the decision of the Board either to give or withhold consent must be given before the expiration of three months from the date of the Joint Committee's application for it.

268. As regards procedure?—Proceedings under the 1876 Act are taken before the County Court; under the 1892 Act, before a Court of Summary Jurisdiction.

269. As regards power of inspection?—Power of inspector of Local Government Board to grant a certificate as to best practical means has been abolished. Power of entry has been granted, for the purpose of taking samples, under penalties for obstruction.

Appendix No. 10.

270. Will you explain the diagram produced and Table A?—The diagram illustrates comparative results of treatment by different methods, namely, by precipitation alone, precipitation and artificial filtration, precipitation and land filtration, land alone. The table which has been put in, marked A, is intended to further explain the diagram, and also contains a summary of the results. The amount of impurity in the samples is expressed in grains per gallon of oxygen absorbed in four hours, one grain being the limit of impurity allowed; this limit is shown on the diagram by a horizontal blue line, and is the limit referred to in the table. The samples were taken at irregular intervals of time, and the inspector's visits were unexpected. Many other visits besides those when the samples were taken were made to the various works, which have been kept under regular supervision, and the samples may be taken to give a good indication of the efficiency of the works. From the summary at the foot of the table, it will be seen that the percentage of samples which came below the limit of impurity—in other words, which were satisfactory—were: From precipitation alone, 18 per cent.; precipitation and artificial filtration, 69 per cent.; precipitation and land filtration, 70 per cent.; land, 83 per cent. From these results it seems clear that treatment which consists of precipitation alone cannot be considered satisfactory. This is fully borne out by experience on the rivers, as is invariably found that effluents of this description, unless largely diluted, decompose in the stream and cause a nuisance. The highest percentage of results obtained below the limit is from land. The results obtained from artificial filtration in conjunction with precipitation are very slightly inferior to those obtained from land filtration in conjunction with precipitation, and seem to indicate that good results may be obtained from the former method of treatment.

271. Are there any particular points in your reports to which you wish to draw attention concerning the action of the Mersey and Irwell Joint Committee with manufacturers?—In my report of October, 1893, on page 23, appears a short summary of the action taken up to that date. From this it will be seen that the matter was brought before the manufacturers for the first twelve months by means of conferences and personal visits to the various works, so that when more active steps were taken later on they had had ample time to make inquiries and decide on what means they should adopt for the treatment of their waste waters. To this gradual action on the part of the Joint Committee is no doubt chiefly due the success which has attended their action and the small amount of friction which has been caused. In the report of March, 1896, this matter is further dealt with on pages 5 and 6, and it is there pointed out that the improvement which had up to that time taken place in the rivers was chiefly due to what had been done by manufacturers, the local authorities, especially the larger ones, being very backward in getting their works completed. In the report of February, 1898, page 14, the matter is brought up to the present year, and the tables on pages 16 and 17 show the progress made; particulars are also put in showing the number of proceedings which have been taken, amounting to 21 altogether, besides 59 applications to the Local Government Board.

272. As to cost of legal proceedings?—The total cost incurred by the Joint Committee in these proceedings, including the cost of the Local Government Board inquiries, amount to less than £900, which shows that there has been no organised opposition, and that the manufacturers recognise the justice of measures being taken for the purification of the rivers.

273. Do Lancashire manufacturers feel hardly used in having to purify their trade waste?—The manufacturers in this watershed feel very strongly, and I should like to bring this promiently before the Commission, that it is only fair that manufacturers all over the kingdom should be compelled to treat their trade waste in the way that those in Lancashire have been compelled to do. The cost of treatment is a definite charge on the cost of production, and it ought to be made general.

274. What is the amount of the outlay to which manufacturers have been put?—The outlay to which manufacturers have been put has been very considerable, and will probably not amount to less than £300,000, besides annual maintenance. The improvement to the river is, however, an important factor, and has been an advantage to many manufacturers in enabling them to use river water for purposes for which they could not have used it a few years ago. Those who settle or filter river water for manufacturing purposes are benefiting by the improvement, and if the rivers are efficiently purified this expense will be saved.

275. What are the usual methods of treatment adopted?—The methods of treatment adopted for trade waste consist usually of precipitation or subsidence tanks either with or without subsequent filtration; in some cases the waste is treated by filtration alone. Cinders are usually used as the filtration medium. It has been impossible during the time at my disposal to prepare for the Commission detail drawings of works in actual operation, but I propose to ask the Commission to allow me to lay before a future meeting plans and particulars of some of the most efficient arrangements which have been put down by manufacturers for the treatment of the various kinds of trade waste. A general report on the subject was laid before the Joint Committee in February, 1893, copies of which I beg now to lay before the Commission; this report contains as an appendix a very valuable report by Dr. Angus Smith to the Local Government Board. I am prepared to go more fully into the questions dealt with in this report if it is the desire of the Commission. As a set off to the cost of treatment of their trade waste, some manufacturers have derived considerable benefit from the retention in the works of raw material which was originally discharged into the rivers. This is particularly the case with paper makers. Wood pulp is now largely used for the manufacture of paper, and any waste of this product is a loss to the manufacturer. That waste was taking place has in several instances been brought home to him by the amount of solid matter collected in the tanks.

Appendix No. 1.

TABLE A.—SHOWING COMPARATIVE RESULTS OF TREATMENT OF SEWAGE BY DIFFERENT METHODS.

The limit of impurity is one grain per gallon of oxygen absorbed in 4 hours.

Name of Authority.	Population.	Number of Samples above limit.	Number of Samples below limit.	Total Samples.	Percentage of Samples below limit.
PRECIPITATION ALONE:—					
Bolton Corporation	130,000 (inclusive of 15,000 from Rural District).	18	0	18	0
Manchester ditto	536,000	34	5	39	13
Salford - ditto	198,000	39	0	39	0
Farnworth Urban District Council	23,758	16	3	19	16
Kearsley ditto	8,000	5	3	8	37
Milnrow ditto	8,600	0	4	4	100
Prestwitch ditto	10,469	11	3	14	21
Whitefield ditto	5,800	7	10	17	59
		130	28	158	18
PRECIPITATION AND ARTIFICIAL FILTRATION:—					
Oldham Corporation	131,463	1	2	3	66
Hyde ditto	30,670	9	6	15	40
Mossley ditto	15,000	0	2	2	100
Astley Bridge Urban District Council	6,200	4	10	14	71
Ashton-in-Makerfield - ditto	900 to this Outfall	4	6	10	60
Atherton (Glasshouse) - ditto	16,500	3	3	6	50
Ditto (Hindsford) - ditto		4	3	7	43
Cheadle and Gatley - ditto	8,206	0	9	9	100
Crompton (Cowlishaw) - ditto	12,900	0	2	2	100
Ditto (Newhey) - ditto		1	6	7	86
Droylsden - - ditto	10,500	1	2	3	67
Failsworth - - ditto	13,500	1	3	4	75
Gorton - - - ditto	15,500	2	3	5	60
Heaton Norris - - ditto	9,010	1	15	16	94
Knutsford - - ditto	4,800	10	14	24	58
Little Lever - - ditto	5,500	0	4	4	100
Littleborough - - ditto	10,900	1	10	11	91
Little Hulton - - ditto	7,000	0	6	6	100
Marple - - - ditto	4,800	3	11	14	78
Norden - - - ditto	3,900	3	7	10	70
Radcliffe - - ditto	26,000	2	9	11	82
Reddish - - - ditto	7,000	3	0	3	0
Royton - - - ditto	13,400	1	12	13	92
Swinton (Swinton) and Pendlebury - ditto	26,000	14	13	27	48
Ditto - (Pendlebury) - ditto		5	10	15	67
Turton - - - ditto	6,500	4	11	15	73
Tyldesley with Shakerley ditto	14,500	9	6	15	40
Wardle (Higher Works) ditto	3,900	0	1	1	100
Ditto - (Lower Works) - ditto		1	8	9	89
Barton (Clifton) Rural District Council	1,500 to this Outfall	0	7	7	100
Bolton (Belmont) - - ditto	700 to this Outfall	0	6	6	100
Stockport (Offerton) - - ditto	6,000 to this Outfall	13	14	27	52
		100	221	321	69
PRECIPITATION AND LAND FILTRATION:—					
Rochdale Corporation	71,400	9	14	23	61
Eccles - ditto	30,000	0	7	7	100
Castleton Urban District Council	5,700	2	0	2	0
Hindley - - - - ditto	19,000	4	16	20	80
Moss Side - - - ditto	23,800	3	3	6	50
Westhoughton (Rogers) - ditto	9,000 to this Outfall	6	7	13	54
Wilmslow (Northern Works) ditto	3,050 to this Outfall	0	2	2	100
Worsley (Boothstown) - ditto	1,150 to this Outfall	2	9	11	82
Chapel-en-le-Frith Rural District Council	14,129	0	3	3	100
		26	61	87	70

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TABLE A.—*continued.*

Name of Authority.	Population.	Number of Samples above limit.	Number of Samples below limit.	Total Samples.	Percentage of Samples below limit.
LAND FILTRATION:—					
Altrincham Urban District Council	12,700	7	22	29	76
Alderley Edge - - - ditto	2,218	0	21	21	100
Ashton-on-Mersey - - ditto	5,000	0	22	22	100
Blackrod - - - - ditto	750 to this Outfall	0	2	2	100
Bowdon - - - - ditto	2,800	1	22	23	96
Irlam - - - - - ditto	4,653	0	2	2	100
Leigh - - - - - ditto	32,000	8	5	13	38
Lymm - - - - - ditto	5,000	0	1	1	100
Stretford - - - - ditto	26,000	0	13	13	100
Westhoughton (Dog Holes) ditto	2,000 to these Outfalls	0	2	2	100
Ditto - (Marsh Brook) ditto		0	5	5	100
Wilmslow (Southern Works) ditto	3,250 to this Outfall	0	21	21	100
Withington - - - ditto	31,000 (including 5,000 from Levenshulme)	2	15	17	88
Worsley (Barton Old Hall) ditto	13,500 to this Outfall	8	8	16	50
Barton (Urmston and Flixton) Rural District Council - - - - -	7,310 to this Outfall	3	6	9	67
Bucklow (Dunham Massey) ditto	450 to this Outfall	3	17	20	85
Ditto (Hale) - - ditto	2,740 to this Outfall	9	23	32	72
Ditto (Northenden) - ditto	1,000 to this Outfall	1	11	12	92
Ditto (Timperley) - ditto	2,015 to this Outfall	6	22	28	78
Bury (Tottington) - - ditto	2,000 to this Outfall	2	11	13	85
		50	251	301	83
SUMMARY.					
Precipitation Alone - - - - - - -		130	28	158	18
Precipitation and Artificial Filtration - -		100	221	321	69
Precipitation and Land Filtration - - -		26	61	87	70
Land Filtration - - - - - - -		50	251	301	83

NOTE.—The total population of some of these Authorities are not yet connected up.

276. You say under "standards." "The words of the "Act, that 'the best practicable and reasonably available "'means' be used seemed to create an elastic standard, "which is always capable of improvement as experience "is gained; in cases of prosecution no difficulty has been "experienced at present in showing that the best avail- "able means were not being used." Of course, the "best available means" are very, very wide indeed, and I wanted to ask you, in the case of very small, confined premises where there is practically hardly any opportunity of doing anything whatever with the refuse, is the law satisfied to allow the refuse to go into the sewers or streams, if the manufacturer can say, "Well, I cannot help it; I cannot do any better"?—Yes; I think if he can show that he cannot by any possibility do any better that the law then would be satisfied.

277. No matter how offensive the refuse was?—Under the Pollution Act, I should say so.

278. And there would be no power in the law to make him enlarge his premises so as to be able to treat it?—If he had land of his own he might then, of course, be compelled to put down works.

279. But you do not think he could be compelled to buy land?—I think if he is quite shut in by works all round as in a town, so that it is practically impossible—I think that is clearly a case where it ought to go into the sewers and be dealt with at the sewage outfall works.

280. My next point is where you say, "Clay land is "unsuitable, not only from the land refusing to pass the "required quantity of sewage, but also from the fact that "during dry weather cracks form on the surface which "admit the sewage direct into the drains without purifi- "cation." Well, now, of course, to say the whole of clay land is unsuitable is a very large order. Are you talking there of grass land or arable or both?—I am talking of both, but principally grass land. Those instances I have had most experience of have been grass land.

281. You find the land cracks, although the sewage is coming over it. Does not sewage alone prevent it cracking?—No, the sewage does not. It is not over it continuously, and during the dry time when the sewage is turned off the ground cracks, and as soon as the sewage is turned on the land it goes down the cracks into the drains. It is impossible to keep the land moist enough to prevent it cracking simply by the sewage.

282. It is?—Yes.

283. You quote one case, but have you more cases than that that could be quoted if necessary? I mean, do you speak with great positiveness about that point?—Yes; I feel very sure about that point. I have quoted Tyldesley, Swinton, and Westhoughton.

284. And other authorities, though they have bought clay land, will not use it, you say?—That is so in the case of Gorton and Royton. I may say that in the case of Westhoughton they took a good deal of trouble there to get over this difficulty, and eventually they had to put down precipitation tanks, and at the present time they are putting down an artificial filter. I think in that case it was quite impossible to get over the difficulty of the clay land cracking.

285. Does it crack to such an immense extent as that?—Yes; the cracks go down six or eight inches in depth.

286. You are speaking principally of grass land?—Yes, principally of grass land.

287. Then I do not quite understand the sentence: "Suitable land in sufficient quantity cannot be obtained except by pumping at great cost." What is meant by "pumping at great cost"?—I mean there is not sufficient land at a level which might be reached by gravitation.

288. I see; you would have to pump it up on to higher land?—On to higher land.

289. Then perhaps when we come to the question of describing the systems of artificial filtration you would give us a little description on that point?—Yes.

290. You have put down, "Those in which organisms perform the function of transforming the organic matter accumulated in the filter," and "those in which the organic matter is periodically washed out of the filter or

the filtering material renewed." Now, have you had personal experience of those?—Yes, I have visited all the works in my watershed at regular intervals, and so I have had considerable experience in the way that each particular kind of filter is manipulated.

291. You have seen it at Manchester—have you seen it at Manchester?—Yes, I have.

292. And have you seen the works at Sutton?—Yes, I have. I have only been there once; I went there last summer.

293. And those of the Oldham Corporation and the Swinton Urban District Council?—Yes, I have seen all those.

294. Now, have you any opinion to offer as to the merits of the one or the other?—The one or the other system?

295. Yes?—Whether washing the organic matter out or the other system?

296. Yes?—I think you get better results from the filter in which it is washed out; we seem to get clearer effluents from them, and they turn out—I think Mr. Scudder will tell you—better on analysis. Of course, they are more expensive—more expensive to construct and more expensive to work. But, on the other hand, they get a larger volume of sewage through them than they do through the filters worked on the other system.

297. You say that the other method has been adopted by many authorities in the watershed. You have seen it often, I suppose?—Yes, I have, often.

298. Particulars as to each case are given in the reports and supplementary reports furnished?—Yes, I have sent them in to you.

299. Quite so. They are your annual reports?—Yes, they are; and at the end of the reports you have particulars as to each sewage works in the watershed.

300. Then you say that failure in both systems where it occurs seems to come from the same cause, namely, the accumulation of organic matter in the filter?—I do not know whether I have made my meaning quite clear there.

301. Yes, I think as far as I am concerned you have. Then I wanted just to ask you whether the results of the analyses are from sewage and trade refuse combined?—Sewage and trade refuse.

302. Yes?—In some cases they are combined, in some cases they are not. Trade refuse is included in some of those cases.

303. In some of those cases that you quote?—Yes. Many of them are from districts where there is no trade refuse to any great extent, or where the trade refuse is dealt with by the manufacturers themselves, and not turned into the sewers.

304. (*Mr. Killick.*) In the statement you have made with regard to the information of the Joint Committee you do not say the basis on which it was appointed. It was rateable value, I believe?—Yes, that was so.

305. You speak of a "limit of purity." The limit of purity which has been adopted by the Committee is to admit the worst effluent possible—to take the worst effluent that we possibly could?—That is so.

306. (*Professor Ramsay.*) Might I ask what the meaning of that question is; I did not quite follow?—Without doing any damage you mean to the stream.

307. (*Mr. Killick.*) Yes. The worst effluent that does not putrify when put into the stream at the particular place where it enters.

308. (*Professor Ramsay.*) That is the limit?—Yes. We give them as large a margin as possible in order to just purify the river; that is all we want to do—to do as little as we possibly can.

309. (*Mr. Killick.*) You say, "The outlay to which manufacturers have been put has been very considerable, and will probably not amount to less that £300,000, besides annual maintenance." What do you estimate the maintenance at?—I estimate the maintenance at about 10 per cent. on the capital outlay; I have gone very carefully into those figures.

310. That is—?—£30,000.

311. Roughly capitalised, £1,000,000?—Yes, that is so.

312. Have you any estimate of the amount spent by the sanitary authorities in the watershed?—Yes, it amounts to about £4,500,000 altogether.

313. The Mersey and Irwell watershed?—Yes.

314. Does that include cost of maintenance?—No, that does not include cost of maintenance. I could not arrive at an estimate of the cost of maintenance as regards local authorities.

315. (*Professor Ramsay.*) Does that include the £300,000?—No; that is for local authorities only.

316. (*Mr. Killick.*) You propose to ask permission to lay before us at a future time plans and particulars of some of the most efficient works for the purification of manufacturers' effluent?—Yes, that is so. I have not had time to prepare the plans.

317. (*Chairman.*) We shall be very glad to accept that kind offer of yours, whenever they are ready?—Very good.

318. (*Colonel Harding.*) In answer to a question just now by the Chairman you said that where a trader had not any land available your Board did not call upon him to carry out anything beyond what was practicable for him. You do not take into account the practicable means as adopted by other traders who might have land?—No, that is so. We cannot judge him really on the same basis as a manufacturer who has plenty of opportunity of carrying out the work.

319. Then in the case of a manufacturer putting down new works, and not providing sufficient land to carry out the "best practicable means," as carried out by other traders, would you insist upon his not starting those works until adequate land had been provided?—I think that certainly he ought to provide land for his purification plant before he started his new works.

320. And you would insist upon that?—Yes, unless he could get his waste admitted into the sewers.

321. But then he might require precipitation tanks, would he not?—Yes, no doubt some of the local authorities would insist upon that. On the other hand in many cases the local authorities admit trade waste into the sewers with no preliminary treatment at all.

323. (*Colonel Harding.*) Has any difficulty arisen in your district in connection with the interpretation of the law in reference to the right of traders to compel local authorities to take their trade effluents?—I am not aware that we have had any definite cases between local authorities.

324. (*Mr. Killick.*) You know the case of Peebles v. Oswaldtwistle?—Yes, but that was not in my district.

325. Is there not a case pending now?—Yes.

326. (*Colonel Harding*). Have you any difficulty in getting local authorities to decide whether they will or will not take trade effluents into their sewers?—There is some difficulty about it no doubt.

327. That is a serious difficulty for you because the means which would have to be carried out by the trader would be very different in the one case than in the other?—Certainly, that is so.

328. Passing on to the sewage treatment, I think you spoke to us about systems of artificial filtration. You divided the systems of artificial filtration into two categories: those in which the organisms perform the function of transforming the organic matter accumulated in the filter, and those in which the organic matter is periodically washed out of the filter, or the filtering material renewed?—Yes.

329. Could you give us any typical cases that we might possibly visit where we could see those two classes of results?—Yes, I can do that.

330. What would be the best case within your district where we could see the first result—that in which the organisms perform the functions of transforming the organic matter?—I should mention Oldham for one, certainly; they have a considerable area of filter beds at Oldham worked on that principle.

331. Do you know whether they are worked intermittently, and if so, what is the intermittence?—Yes, they are worked intermittently. The sewage is turned into the filters, they take about one and a-half hours to fill, and they are left full for three hours with the sewage. The sewage is then run off into the stream, and an interval is

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allowed before the next filling takes place. That interval varies with the amount of sewage which is coming to the works at the time.

332. What is it on an average?—It would average—well, certainly six hours, I should say, except in very wet weather. In dry weather the periods of rest are considerably longer.

333. In that case what is put upon the filter is the effluent from precipitation works?—Yes, from precipitation tanks.

334. And what are briefly the results you have noticed from these filters; are they satisfactory?—They have been very satisfactory, yes.

335. Could you give us an example, a typical case where we could see filtration of a mechanical sort, where the organic matter is periodically washed off or removed?—Yes; I think Royton, in the Mersey and Irwell watershed, would be a typical case, and I may also mention Chorley, which is not in the Mersey and Irwell watershed, but which is in the Ribble watershed; that is a very good typical works where the effluent is treated in this way.

336. Have you within your area any instances at all where crude sewage is dealt with on bacteria beds?—Only experimental—nothing that I can really recommend to the Commission.

337. Where is it treated experimentally?—At a place called Thorniley.

338. Have you any idea how it was worked?—No, I have not seen it worked. I heard that they had started it. It has only been at work a short time. I do not think it is really a typical case at all for or against. I should not like to pass any opinion upon it.

339. As to the Manchester experiments which have been carried on under the direction of Sir Henry Roscoe, what principle are they based upon?—They are based upon the first principle, of holding up the sewage in the filter beds.

340. Do they deal with the effluent from chemical precipitation?—Yes. That is a place you should certainly see; they are small experimental beds.

341. What is the area of the beds?—I cannot give you that. Mr. Scudder will give you that.

342. I will reserve that question then.

343. (*Dr. Russell.*) You have told us about the very great outlay incurred by manufacturers in order to provide a proper effluent, and you gave the case of a man who because of the area of his works could not help himself at all, and I think you said you would take his refuse into the sewers and it would be treated with the general mass of sewage. That is correct, is it?—Yes, I think that is the best way of dealing with a manufacturer who is so hemmed in.

344. How do you adjust the apparent inequality of treatment? Have you a special rate for the man who is thus saved great expense?—No, but I think there ought to be a special rate. I should certainly advocate that. I think the manufacturers ought to pay for going into the sewers in order to bring them all on the same basis.

345. (*Professor Foster.*) You speak of your test. What you take as your standard is the absence of putrescibility at the entry of the effluent into the stream?—That is so; that is practically what it comes to. That is what we try to obtain.

346. Without regard to any ulterior changes which may take place down the stream?—Oh, certainly, that would be considered.

347. It would be considered?—Oh, certainly.

348. So that by "at the entry" you do not really mean at the entry?—I mean this, that the effluent as it discharges into the stream would not be subject to any secondary decomposition of that kind; it should be such that it will not make the river a nuisance at all.

349. I do not know whether I should ask you or Mr. Scudder this. In the table which forms the last page of your abstract, are these all the instances of sewage treatment?—Are they all that we have had?

350. Yes; is this a complete list of all the cases where sewage is treated within the area?—Yes, this is a complete list of the samples which have been submitted officially to the Joint Committee

351. And these samples have been taken from all cases where sewage is treated definitely within the area?—Yes, that is so.

352. And you have given a certain classification?—Yes.

353. But each of these categories, I suppose, is capable of subdivision?—Well, it is in some way.

354. Precipitation, for instance, is that always the same in every case?—I must explain that in a few cases, Manchester, for instance, which is under the head of precipitation, we have had, I think it is, five samples from land treatment; they had an area of land of thirty acres which was set out, and five of those samples were taken from land treatment.

355. Is precipitation simply subsidence without assistance or with assistance?—With assistance.

356. With chemical assistance?—With chemical assistance.

357. And that chemical assistance varies in different cases?—That is so.

358. And artificial filtration—there, of course, you have two kinds of artificial filtration?—Yes.

359. And there are subdivisions of those?—Yes, there are. It is very difficult to divide them exactly into two categories.

360. But there are a great many?—There are a great many different systems.

361. Is it possible to obtain information as to those different systems?—No, it is not impossible; that information can be obtained. For instance, Turton I may mention as a case in point, where they take the whole of the filtering material entirely out periodically. It is not washed in situ; as soon as it gets foul the whole thing is taken out and re-charged with cinders.

362. I would suggest that it would be very desirable to have some brief and succinct statement of these various methods which are here classed together under the phrase "artificial filtration."

(*Chairman.*) Yes.

363. (*Mr. Killick.*) There would be no difficulty in presenting that at the next meeting, would there?—No.

364. We should be very glad to present that when Mr. Tatton presents the description of individual works?—There would be no difficulty about that at all.

(*Chairman.*) That would certainly be very valuable.

365. (*Professor Foster.*) Would there be any difficulty in distinguishing any of those different systems when they are applied to household sewage only, and when they are applied to household sewage mixed with refuse, and also at the same time to indicate the dominant refuse—not exactly the details, but whether, for instance, paper works are the dominant industry?—I could get you that information in most cases, certainly.

366. (*Mr. Killick.*) I believe that information really is in the documents you have presented, though it is not on that sheet; the reports you present from time to time contain that information, do they not?—Yes.

367. (*Professor Foster.*) But scattered?—Yes.

368. Could we have it put to us for our convenience in a succinct form?—Yes.

369. Will each member of the Commission have a copy of those reports?——

370. (*Chairman.*) Can you manage that?—Yes.

371. (*Professor Ramsay.*) I notice that in the table at the end the limit of impurity is one grain per gallon of oxygen absorbed in four hours; is that an arbitrary limit; who imposed that limit?—That was suggested by Sir Henry Roscoe. Mr. Scudder is the chemist, and I think you might ask him about that.

372. Then I was going to ask as regards the filtering material. Perhaps this point should be referred to. Are there various kinds of filtering material alluded to in the two divisions of artificial filtration to which you refer?—Yes, there are.

373. That is also a part of the variation?—Yes. In some cases cinders are used; in some cases sand mixed with other materials.

374. Another question is as regards the relative areas. Do they require the same amount of land?—That varies very much indeed.

375. I mean for the same quantity of sewage. Would each of the sub-divisions require the same amount of land? —No, that varies. We have that set out in those reports that I have laid before you, and those reports show that the area varies both in land and also in artificial filters.

376. I mean in filter beds?—Yes, it does vary considerably.

377. Which would you say required the least space of the two systems?—The first system where the organisms perform the function of transforming the organic matter accumulated in the filter—this requires a larger area than the other.

378. Then another question. I really do not know whether I am right in putting such questions to you or whether I should wait for Mr. Scudder; perhaps you will stop me if necessary?—If I cannot answer them I will tell you.

379. Then I want to ask what is done with the wash water of the filter?—In some cases the wash water is pumped back into the tanks and treated over again.

380. With precipitants?—Yes, precipitated over again; and in other cases the wash water is run on to an area of land where it is allowed to filter through the land.

381. In no case it is run direct into the stream?—Oh, no.

382. (*Major-General Carey.*) Is it your duty to decide as to the best possible means which have been adopted by the manufacturer for rendering the effluent harmless?—We have not really, I was going to say, come to that yet. I suppose in a case in court where it had to be fought out the manufacturer would have to show that he was using the best practicable means, and it would be our business to show that he was not.

383. But on the actual mode of procedure what happens in the inspection of the works—do you inspect the works?—Yes, I do.

384. To ascertain what has been done?—Yes.

385. And to report to the Joint Committee?—Yes, that is so. If the effluent from a works is unsatisfactory, I do report to the Committee if I think it is impossible for the manufacturer to carry out any further works.

386. You would take samples, I suppose, of the trade effluent for analysis?—Yes, I do.

387. What standard do you use for deciding whether the effluent is good enough to be put into the river or not?—Up to the present time what we have endeavoured to do is to prevent solid matter being discharged into the river. If the manufacturer moves all his suspended solids out of his effluent, and if nothing settles out of the sample after standing for a day or so, that is taken as satisfactory.

388. That is the limit: the manufacturer must move all the suspended matter?—That is as far as we have got at present.

389. That is what I wanted to know. On that you decide whether the effluent should be passed or not?—Yes, that is so.

390. You do not deal with the matter in solution?—We find that if there is a large amount in solution it settles out in the sample very soon. That is also mentioned in the analysis; the matter in solution is also taken into consideration with that in suspension.

391. Do you consider there is any difficulty in treating trade effluents satisfactorily if the works are suitably placed?—In the case of some manufactories there is great difficulty; in the case of fellmongers, for instance, it is a difficult effluent to treat; they want a large area of filtration or of land. I think as regards most manufactories, dyers, calico printers, and bleaching works, there is no difficulty about it.

392. Do you inform them what works they ought to undertake to purify the effluent, or is it left to the manufacturers?—We do not officially inform them.

393. Is it left to the manufacturer to call in separate advice?—It is left to the manufacturer to call in separate advice; I do not officially advise them at all. I give them assistance in going round.

394. When you report to the Joint Committee that the effluent is not sufficiently good to be passed into a stream that report is accepted, I presume, or is it subject to revision?—An analysis is made of the sample by the chemist, and he reports whether it is satisfactory or not, and I should report then to the Committee whether it would be possible for the manufacturer to carry out further works.

395. As to treatment on land, I see that it is admitted here that land is the most suitable means of purification if it can be obtained and is suitable for the purpose?—I should certainly say that.

396. It is the best mode of purifying sewage?—Yes.

397. That is the conclusion at which the Joint Committee have arrived, is not that so?—That is so.

398. As regards these unsuitable soils. Take the clay soils. Have not the districts attempted to improve these clay soils by taking out the clay and burning it, and replacing it or otherwise finding a better filtering medium?—That has been done in the south, I believe, at Wimbledon.

399. They have not attempted it in the north?—They have not attempted it in the north, no. That comes very expensive; that is practically making a filter bed.

400. Yes. Of course it is expensive except when the total area of land is not very great?—Yes.

401. But they have not attempted anything of the kind in the Mersey and Irwell watershed?—No, I do not think it has been done anywhere.

402. They have simply rejected clay soil as unsuitable?—They have preferred to construct filter beds.

403. They have given up the idea of using the land for filtration and adopted this other system of precipitation and artificial filtration?—That is so. They can get cinders, as a rule, pretty cheaply, and it comes less expensive to make a filter bed of engine ashes than to burn the clay into burnt ballast and to make it into a filter bed in that way.

404. I think you say that in a large proportion of the works where the sewage was treated by precipitation and filtration, in that case representing fifty per cent. of the population, the results were satisfactory?—Yes, they were satisfactory.

405. Those results were satisfactory, and the rest unsatisfactory?—That is so.

406. Are those results based on any standard?—That was the standard which has been adopted, and on which those diagrams are drawn up, of one grain of oxygen absorbed.

407. That has been the sole test?—That is so.

408. In those cases where the effluent has been unsatisfactory they have never attempted apparently to use land which I presume they have obtained. In all those cases where chemical treatment and precipitation and artificial filtration have been adopted there is land in the majority of cases—the authorities have obtained the land?—Yes.

409. But they have not used it; they have given it up?—In some cases they have used it; in others they have not. In those cases I mentioned—Tyldesley, Westhoughton, and Swinton—they used the land.

410. In addition to the filtration?—No; that was before they adopted filtration.

411. I mean in addition to the filtration?—Oh, that is so.

412. These unsatisfactory results, could not they have been partly remedied, possibly entirely, by passing the effluent on to land afterwards?—After the filtration?

413. After the filtration?—I think that that would very likely have been of assistance, but in the case of clay land you simply pass it over the surface.

414. Unless it is prepared as I suggested—unless a better filtering medium has been artificially prepared?—Yes. No doubt you could make it into a filter.

415. Yes, as it has been done, as you said?—Or you might have an artificial filter, and then pass the effluent from that filter bed over the surface of the land, as they do, in fact, at Wimbledon.

416. What I mean is, there seems to be no possibility of the defects being remedied unless they enlarge their works, or practically reconstruct them, or use the land as supplemental after ordinary artificial filtration. Of course, as regards this last table (*a*), you have promised, I think, to let us have all the conditions under which these results have been obtained?—Yes, I have.

Mr. R. A. Tatton, M.I.C.E.
12 July 1898.

417. I see in one case, Oldham Corporation, with a population of 131,000, only three samples have been taken altogether?—That is so; the works have only been opened a short time.

418. In the case of land schemes, you would be able to let us know what the area and quality of the land was?—Yes, I can do that.

419. On which the sewage has been treated?—The area you have in these reports in tabular form—at the end of these reports.

420. (*Mr. Killick.*) You will bring that all into one table, as promised?—Yes.

421. (*Sir Richard Thorne.*) I wanted to ask you one question with regard to the term "the best practicable and "reasonably available means." Do you apply that equally to the pollution of an existing fouled stream and the pollution of an existing perfectly unfouled stream?—Should I apply that standard?

422. Yes?—Yes, I should.

423. Then, if you have an effluent which is admittedly difficult to purify, and some remain admittedly foul, you would deal no more severely with a man who begins to foul an existing stream hitherto altogether unpolluted than you would with a man who pollutes the foulest stream in your area?—The endeavour is to prevent the fouled stream from being polluted.

424. How do you do that if, after he has used the best practicable and reasonably available means, his effluent still remains absolutely foul?—You mean to say that the stream remains foul.

425. No; his effluent remains foul, and he is fouling a stream which hitherto has been, say, a fishing stream. Have you any means of dealing with him any more severely than with a man who fouls a stream such as flows through Manchester?—No, we have no different means of dealing with him.

426. You have no power to prevent existing unpolluted streams from becoming foul?—No extra powers, no additional powers.

427. You have no power if the foul effluents must go in, and you admit, do you not, that some effluents will remain foul?—Yes. We have no power so far as I know to prevent a manufacturer starting new works on a clean stream, and polluting that stream to some extent.

428. I am not quite sure that I follow exactly what you mean in your statement under "Liquid Manufacturing "Pollution," where you seem to imply that whatever is required in Lancashire should be required in every part of the country. Do you mean on the part of the trader or on the part of the authority dealing with the refuse in the two different sets of places?—Well, I should say in both, but in that particular sentence it referred to the trader. What I wish to imply is that it is hard upon the traders of Lancashire to be put to the extra cost of treating their trade waste, which really means an extra cost on the production, while the rest of the traders in other parts of the country have not that additional expense put upon them.

429. (*Professor Foster.*) The effect of that really is to drive trade away from Lancashire?—That is what it tends to do, no doubt.

430. (*Sir Richard Thorne.*) At the same time, I gather from what you put to us that the improvements manufacturers have had to carry out at their own cost have been of personal advantage to themselves?—In some cases they have, but not as a rule.

431. It is not general?—No, it is not general.

432. Of course, one is at once confronted with the fact that the manufacturer pollutes the stream for his own personal profit, and for nobody else's; that is the object of his factory, is it not?—Yes.

433. And he can get a further advantage for himself by lessening the pollution of the stream in many cases?—He does not improve the stream above him by reducing his own pollution.

434. It would be rather collectively?—Yes.

435. But he saves, does he not, sometimes?—Yes; paper-makers do.

436. But that is not very general?—That is not very general.

437. You agreed, I think, in answer to a question which one of the other Commissioners put to you, that it would be fair to make the manufacturers pay something for allowing their waste to enter into the sewers?—I think so; I think that would bring them all on to the same basis.

438. Would it be equally fair to make them pay for taking any refuse into streams which in any way fouled them?—I should make them purify it.

439. But you admit that there are some things which cannot be purified?—It is a very difficult thing to know how to assess that.

440. If it could be assessed, would it not be a fair thing to do?—I think it is very unfair upon those below, certainly.

441. You have a man above who, for his own personal profit, pollutes a stream and damages the interests of those below. Would it not be fair that he should at least in some way compensate by an assessment or otherwise those whom he injures?—If it damaged those below, those who were damaged by him could take action against him.

442. But that does not protect the poor man; it requires money to take proceedings?—I should not be inclined to allow a man to buy himself into polluting a stream. I should not like a manufacturer to have the power of acquiring the right by purchase of polluting a stream.

443. Not if he has used the best practicable and available means for preventing the pollution of the stream?—I do not think that should be recognised.

444. But he now has the right to do it, has he not, so far as you are concerned, without paying anything for it?—By going into the sewers, you mean?

445. No. You allow the refuse to go into the stream if he has done the best that he can to free it from contamination, as I understand?—Yes, that is all the power we have.

446. Then he practically has the right, so far as you are concerned, to take his effluents into the stream now without purchasing his right?—When he has used the best practicable means.

447. Yes, and if it still then pollutes it, you do not think it would be fair to ask him to pay anything for it?—I really have not considered that point; I do not think, on the face of it, I should like to let him acquire a right to pollute.

448. Can you give me any general idea at all as to whether it is a substantial increase of cost to the sanitary authorities in dealing with their sewage effluent if they receive manufacturing refuse? I am speaking of manufacturing refuse generally, because I know your answer must be quite general?—Yes, I think it does increase the cost. In the first place, it increases the volume, of course, by the amount of manufacturers' waste which is turned in, and also it makes the sewage more variable; that is to say, sometimes it is of a different character when the manufacturers' waste is being turned down, than it is at others, when it is purely domestic sewage.

449. Would it be very difficult to assess the amount of increase of cost so as to require a payment for admission of manufacturing refuse into sewers?—Well, it would be very difficult to get it exactly right, no doubt. I should be inclined to put it on the volume which they turned in.

450. Irrespective of the quality?—I think so; I think that is a more easy basis to put it on.

451. Would some such payments be a very great incentive to manufacturers to purify their refuse?—To purify it on their own account?

452. Yes, before it goes into the sewers?—Well, I should insist upon their purifying it if they can do so.

453. Under any circumstances?—Yes, under any circumstances. It is only those instances where they cannot do it.

454. One word more with regard to your tables at the end of the printed memorandum. I suppose that those cases in which you get one hundred per cent. of samples below the limit, are those which are most pure?—Yes, that is so.

455. And you contrast precipitation and artificial filtration, and precipitation and land filtration, and they are practically the same. The former is 69 per cent. of samples below the limit, and the latter gives 70 per cent. of samples below the limit?—Yes, that is so.

456. Now I notice that in the precipitation and artificial filtration series, you have eight cases out of 32 in which you get what would be perfection from your point of view—that is, one hundred per cent.?—Yes.

457. Now you probably have noticed that out of those eight cases in which you got those good effluents, in six instances out of the eight the number of samples examined was only from one to nine?—That is so.

458. Should I be right in assuming that any estimate formed from those would be of the very roughest character. For example, you get 100 per cent. on one single sample examined?—Yes. The reason why that is is that if works are usually satisfactory, usually found to be so, the samples that are taken are not always so numerous as where they are usually unsatisfactory. They are not so often before the Committee; that is really the reason for that. For instance, if you take Mossley; Mossley has not been at work very long. That is the third on the list.

459. There were only two samples taken, I see, with 100 per cent. below the limit?—Yes.

460. 100 per cent. has very little meaning on two, and still less on one?—I admit that that is so, but that explanation that I gave I think makes a difference.

461. Your explanation you think would eliminate that source of error to some extent?—Yes. If we had had an equal number of samples from each works it would not have made any practical difference in that.

462. I notice that in the precipitation and artificial filtration even with that source of error you only get 8 out of 32 in which you get the 100 per cent.?—That is so.

463. But in land filtration you get 9 out of 20?—In land filtration?

464. Nine out of twenty reached 100 per cent. of samples below the limit?—Yes.

465. That confirms what you said as to land filtration being far superior to the other?—I quite agree that land filtration is far superior to the other. I should only sanction artificial filtration if suitable land cannot be obtained.

466. You get 69 per cent. of samples below the limit with precipitation and artificial filtration and 75 per cent. in the case of precipitation and land filtration, but in the former series you have 321 samples examined, and in the latter only 91?—That is so.

467. Does that introduce a source of error at all in forming any conclusion?—Of course you have not so many samples to go on.

468. In other words, do you think, that notwithstanding, they are still fairly comparable?—I think they are.

469. One more word and I have done. You say you do not advise officially in your district as to what should be done to prevent the pollution of streams?—That is so. *Mr. R. A. Tattm, M.I.C.E.* 12 July 1898.

470. How do you advise then?—Well, in going round to a works—suppose I went to a manufacturer, and he said he could not carry out any works, there was nothing he could do, I should then suggest that he might do so-and-so and so-and-so, and as a rule I have found that that has been fairly successful.

471. Does not that hinder you at all in finding fault with him afterwards?—Not the least. I have found no difficulty in that at all. Of course, if you put it to him that if he does so-and-so and so-and-so it would be satisfactory; that might cause difficulties afterwards.

472. True?—But I have not.

473. I was thinking if a man had done what you told him, and still having a foul effluent, and being summoned to appear before the Committee, his answer would be: "I have done what your inspector advised me; what more can you expect"?—I think that would be rather a difficulty; I grant that; but I have had no instances.

474. On the whole you would admit that anyone holding an official position as you do towards the Board ought not to advise?—Not officially; I should agree that the inspector ought not to advise officially, and I always tell the manufacturer that—that any advice that I give him is entirely without prejudice, and it is not officially from the Committee.

475. And you have not found that any hindrance in your work as yet?—No, I have not.

476. (*Mr. Killick.*) It was agreed by the Joint Committee that we should give all the help possible both to the authorities and the manufacturers in the treatment of effluents, was it not?—Yes, that is so, unofficially.

477. And you were asked to give any help you could do?—Yes.

478. You have not made it in any way a business to give help. Have you received any fee or remuneration whatever for giving that advice?—No, none whatever.

479. (*Sir Richard Thorne.*) Your whole services are taken up by the Committee, I suppose?—Oh, certainly, that is so. I should make that quite plain.

Mr. Frank Scudder, F.C.S., F.I.C., called in; and Examined. *Mr. F. Scudder, F.C.S., F.I.C* 12 July 1898

480. (*Chairman.*) You are a Fellow of the Institute of Chemistry of Great Britain and Ireland, and Chief Scientific Assistant to Sir Henry Roscoe, F.R.S.?—Yes.

481. You have formerly been assistant to the late Dr. Angus Smith, who was one of the inspectors under the Rivers Pollution Prevention Act of 1876?—Yes.

482. And you have been requested to appear here by the Mersey and Irwell Joint Committee as chemist to that Board with the object of describing the chemical portion of the work which the Joint Committee have been concerned with?—That is so. I may add that Sir Henry Roscoe is the Scientific Adviser to the Mersey and Irwell Joint Committee, but I am the Acting Chemist under the supervision of Sir Henry Roscoe.

483. When was Sir Henry Roscoe first consulted by the Joint Committee?—In November, 1891.

484. For what object?—An opinion had been expressed that it might be desirable, if possible, to define the maximum amount of pollution to be allowed, and the question was referred to Sir Henry Roscoe for his opinion.

485. What opinion did Sir Henry Roscoe express respecting the desirability of adopting standards of purity?—Briefly stated, his opinion was adverse to their adoption. I hand in a copy of his report dated November 23rd, 1891, giving reasons for the opinion expressed:—

"10, Bramham Gardens,
"Wetherby Road, S.W.,
"November 23rd, 1891.

"Dear Sir,—With regard to the question which you put to me at my interview with Mr. Hibbert and yourself on Thursday last, respecting the desirability of adopting standards of purity, as given in the report of the Royal Commission appointed by Parliament in 1868, I have to say that I believe such standards to be altogether impracticable for the Mersey and Irwell Watershed. Moreover, I do not think that the proposal made by the Salford Corporation in the letter of the Town Clerk of July 22nd last, in which they propose to take a standard of three times the quantity of impurities, as recommended in the Commissioners' Report, as being reasonable compliance with the Act, would work any more satisfactorily. On the contrary, I am strongly of opinion that no general commercial standard of purity of effluent can be maintained, and for the following reasons: First, because, as I pointed out to you, the conditions of the streams vary with the time of the year; secondly, because each industry must require a different standard, inasmuch as the impurities sent out from one works may be much less hurtful than those from another, although the former may be present in larger quantities; thirdly, because a standard which may be fair at the head of a stream, such as the Irwell, would not be fair on the same river at Manchester.

"Hence, in my opinion, the only way of dealing with the question is: First, to insist that no solid matter should be thrown into any watercourse, or placed so as to fall into it; secondly, to insist on all manufacturers using the best practicable means for rendering their effluents harmless, so as to cause no pollution of the water into which it flows. If the best practicable means are adopted, it is all that can be attempted without injury to trade. Another advantage is, that the same will apply to sewage pollution as well as to manufacturing pollution.

"The Inspector must decide whether the best practicable means have been employed, and thus a constant advance will be made by insisting that the satisfactory process in one case should be carried out in another, and, by degrees, commercial standards may be obtained to suit each class of pollution.

"I am,
"Yours faithfully,
"HENRY E. ROSCOE.

"Fred. C. Hulton, Esq., Preston."

486. Do you wish to make any further reference to this report?—Yes, I desire to call the attention of the Committee to the proposal of the Salford Corporation referred to by Sir Henry Roscoe, and to say that the adoption of such standards would not assist in attaining the object of

Mr. F. Scudder, F.C.S., F.I.C.
12 July 1898.

the Rivers Pollution Prevention Act of 1876, and would tend to stultify their action, inasmuch as grossly polluting effluents would be allowed to pass into the rivers with such standards in force.

487. What action did the Mersey and Irwell Joint Committee take on receipt of Sir Henry Roscoe's report?—They decided to abandon the suggestion to define the maximum amount of impurity to be allowed for the reasons given by Sir Henry Roscoe.

488. When was Sir Henry Roscoe again consulted, and with what object?—On December 7th, 1891, the Joint Committee retained Sir Henry Roscoe to make a preliminary report on the condition of the various works in the Mersey and Irwell basins, as polluting the streams in that district, and also as to the best means of preventing such pollution.

489. Did Sir Henry Roscoe present to the Joint Committee a report?—Yes. I beg to hand in copy of Sir Henry Roscoe's report, dated March 26th, 1892.

PRELIMINARY REPORT BY SIR H. E. ROSCOE, M.P.

"Manchester,
"March 26th, 1892.

"Mersey and Irwell Watershed Joint Committee.
"To the Chairman of the Joint Committee.

"Sir,—I may commence this Preliminary Report by stating my opinion that of the two sources of pollution, viz., sewage and manufacturing refuse, the first is by far the most serious. With the sewage, however, I am not at present concerned. As regards the second, upon which I have to report, I may remark that the practical question is not whether the waters of our Lancashire rivers can ever be made fit for domestic use, but by what means they can be rendered inoffensive.

"I am also of opinion, as expressed in my letter to your Clerk of November 23rd, 1891, that the application of uniform standards of purity, so far as manufacturing processes are concerned, to rivers throughout the watershed, is inexpedient, but that, in every case, the best practicable means for preventing pollution must be adopted.

"The first necessity is, that all solid matter must be excluded from the stream, according to Clause 2 of the draft of 'The Mersey and Irwell Joint Committee Act, 1892," and, in my opinion, this can be effectively done without interfering materially with manufacturing interests. The question of liquid pollution is a more difficult one, and requires special inquiry into the nature and amount of the various effluents; and the present report mainly refers to this part of the subject.

"On commencing the inquiry, I was furnished with a report issued by the Rivers Committee of the Manchester Corporation, dated September, 1891. This report contains a list of 296 works on the banks of the river Irwell and its tributaries. From this list I selected a certain number of works to be visited as representing the various trades on the bank of the river. Together with these I added several works situated in the Mersey Watershed. In all, 41 works, carefully selected as typical, have been visited and inspected, and thus evidence obtained to enable me to advise the Committee as to the best steps to be taken to prevent pollution.

"The works inspected are classed under the following heads:—

"1. Calico Printing and Dyeing (15 works visited).
"2. Bleach (6 works visited).
"3. Wool Scouring, Fulling, and Felting (4 works visited).
"4. Paper Making (5 works visited).
"5. Tanneries (2 works visited).
"6. Fellmongers (1 work visited).
"7. Silk Dyeing (4 works visited).
"8. Chemical Works (4 works visited).

"*Firstly.*—CALICO PRINTING AND DYE WORKS.—With regard to both these trades, it is well to remark that, since the introduction of artificial colouring matters, and of wood extracts instead of madder root and of the wood itself, the pollution arising from these works is very much less now than formerly, although, even at present, a considerable amount of pollution does exist. This pollution, however, is mainly confined to a portion of the total amount of water employed. The volume of effluent is very large, and serious pollution must continue so long as all the wash waters are allowed to mix with the waste liquids from the various processes. The treatment of so large a volume is a serious question, but much less so if the manufacturer were advised to separate the 'wash waters' (which might, without serious damage, be returned to the stream, as they contain no solids, and are only, as a rule, slightly coloured) from the more concentrated and impure waters which require treatment. The manufacturer would then have only thoroughly to cleanse a portion of the total amount of effluent.

"The process of purification to be adopted must obviously depend, as the Royal Commissioners reported in 1870, upon the position of the manufacturer on the stream, the space at his disposal, and other circumstances.

"Efficient methods for purification of the foul effluent are well known, and how this is to be accomplished, whether by means of subsidence (with or without the addition of chemical agents) or by filtration, is a question which each manufacturer must settle for himself. In cases where land is not available, either for filtration or even subsidence, the desirability of allowing the manufacturer to pass his fouler effluent, or a portion of it, direct into the sewer must be considered.

"I may state that the effluent from this class of works would not have any injurious effect on the sewers, provided that solid matter and sludge are excluded.

"*Secondly.*—With regard to the effluent from BLEACH WORKS, the pollution is not of a serious character. It consists exclusively of a solution of chloride of calcium, containing, in some cases, traces of free chlorine, which may be thrown into a river in considerable quantities without rendering the water offensive; on the other hand, the entrance into the stream of the lime sludge, derived from the manufacture of bleaching liquor from bleaching powder, must be strictly prohibited.

"*Thirdly.*—In the case of WOOL-SCOURING, FULLING, and FELTING WORKS, the pollution is serious. The effluent contains alkali, soapy and oily matters, fullers' earth, and blue colouring. The oils, which are derived not only from the soap used in the process of manufacture, but also from the natural oil existing in the wool, are combined with a portion of the alkali. At one of the works included in this class, a method of purification has been adopted, which I have personally inspected, and which I found to be perfectly efficacious. This is done by chemical precipitation and subsequent filtration. The cost is inconsiderable, and is rendered less by the fact that much of the refuse oils and fats can be regained. I have no hesitation, therefore, in advising that all works of this class should be compelled to adopt similar means for the purification of their effluents; indeed, it is satisfactory to learn that, the attention of other wool-scourers having been called to the character of this process, the adoption of the plan is likely to become general.

"*Fourthly.*—PAPER MAKING is a very large trade on the streams, and is the cause of a serious amount of pollution. Great progress in utilising the waste material has, however, been made during the last few years, and several paper manufacturers on the stream already do all that is practicable in this respect. Others, however, are less careful, and measures must be taken to insist upon these taking like precautions. These precautions are, (1) in preventing the dirt from rag washing, lime, fibrous matter, etc., from passing into the stream (this is accomplished by subsidence); (2) in the evaporation of the soda liquors derived from the boiling of the esparto, straw, etc., this latter process being remunerative. The large volume of water used in the manufacture for washing purposes may, without damage, be admitted direct into the river, provided means be taken to prevent the passage of waste fibrous material.

"*Fifthly.*—TANNING.—The direct entrance into the streams of all liquids, as well as solids, from tan-yards must be strictly prohibited, as the effluents are of a very offensive and putrescible character. They possess, however, manurial value, and where sewers exist these liquids may, with propriety, be sent down them, especially as their volume is not large. In cases where sewers do not exist, a special treatment must be adopted. No attempt has yet been made by any tanner on the streams to purify his effluent.

"*Sixthly.*—FELLMONGERS.—In this trade the waste products are very offensive. At present the whole of the foul liquors go direct into the streams, polluting the water for a considerable distance. Where sewers exist, the liquids, after subsidence, might be then got rid off. In other cases, some method of purification, such as is used in the case of sewage, must be adopted. In one works preparations for such a treatment have been made, but not yet

put into operation. It is very advisable that this should be done at once.

"*Seventhly.*—SILK DYEING.—Formerly, the waste products from this trade polluted the river considerably, but at present there is little more to complain of than the admission of coloured water. The worst of this should be separated and filtered, as in the case of calico printing and dyeing works.

"*Eighthly.*—CHEMICAL WORKS.—In the case of chemical works, the variety of materials used, and of the products made, is so great that it is impossible to report upon these as a class. In each case, special examination must be made, and care taken that the best practical means to prevent pollution is adopted. Several works were visited, but no serious pollution was observed, except in the case of tar works, in which sulphate of ammonia is manufactured. In this process lime sludge is run into the river. This must be stopped by putting down depositing tanks for subsidence and cooling. By this means, the larger portion of the tarry matter, which at present enters the stream, would also be arrested. This plan is in operation in one works.

"In conclusion, I may add that my investigation has shown that very much may be done to improve the condition of the streams by careful inspection and friendly communication with the manufacturers, who have met me in a most conciliatory spirit, and this without interfering with the important trades of the district, or harassing the manufacturers in carrying out their processes.

"I am, Sir,

"Yours truly,

"HENRY E. ROSCOE.

"The Right Hon. J. T. Hibbert."

490. I notice that this report refers exclusively to manufacturing pollution?—That is so.

491. You were not concerned and had not been consulted by the Joint Committee with regard to sewage pollution at this date?—No.

492. Did you yourself visit the works referred to in this report?—Yes; all of them.

493. I may take it that you agree generally with the statements and conclusions of the report?—Yes.

494. What action did the Joint Committee take with regard to this report?—They resolved that a print of the report be sent to each of the manufacturers who caused any pollution to the rivers and streams in the district of the Joint Committee. This report formed the basis of my evidence which I gave before the Police and Sanitary Committee of the House of Commons, in May, 1892, when the "Mersey and Irwell Prevention of Pollution Bill" was considered.

495. Will you please state briefly the main features of the report?—No. of works selected, 41. Classification of Works.—1. Calico printing and dye works. Considerable amount of pollution exists. Volume is very large. Necessity of separating the more concentrated and impure waters from the "wash waters," so as to minimise the volume of water to be treated daily. Processes of purification. 2. Bleach works. Cotton bleaching. Waste bleaching. Nature of waste liquors. Methods of purification. 3. Wool scouring, fulling, and felting works. Nature of waste liquors. Offensive character. Process of purification. 4. Paper making. Nature of waste liquors. Process of purification. 5. Tanning and fellmongering. Nature of waste liquors. Process of purification. 6. Silk dyeing. Nature of waste liquors. Process of purification. 7. Chemical works.

496. When was Sir Henry Roscoe appointed scientific adviser to the Joint Committee?—The Mersey and Irwell Joint Committee on March 6th, 1893, considered the advisability of appointing a chemist to advise the Joint Committee upon the pollution arising from manufactories, and they resolved to appoint Sir Henry Roscoe as their chemical adviser, and on March 9th Sir Henry Roscoe commenced to carry out the inspection of works and to advise the Joint Committee on the line of action proposed to be taken. Conferences between the Chemical Sub-Committee of the Mersey and Irwell Joint Committee and representatives of firms engaged in various manufacturing processes were held in May and June, 1893, for the purpose of considering the possibility of so dealing with noxious or offensive effluents passing into streams adjacent to their respective works to prevent them from being offensive and injurious to public health.

497. What result had these conferences?—The result of these conferences was that the trades representatives generally expressed their readiness to comply with the requirements of the Committee, and erect plant for the satisfactory treatment of their foul waters, with the result that by the month of October good progress had been made and considerable enthusiasm was created to satisfactorily solve the problem. It was, however, found necessary to summon at least 106 manufacturers out of a total of 390 before the Joint Committee to show cause why action should not be taken against them, and it is very satisfactory to have to point out that during a period of six months following the date of these conferences, only eight cases required the intervention of the Local Government Board, who, after holding an inquiry as the Act requires, decided to consent to further proceedings being taken in these eight cases. The manufacturers have steadily been constructing purification works, and the Joint Committee have brought pressure to bear on those manufacturers who have erected inefficient works to improve them, and the response which as a rule has been given to these intimations was of a satisfactory character. On September 2nd, 1895, Sir Henry Roscoe presented a report to the Mersey and Irwell Joint Committee on "Manufacturing Effluents."

SPECIAL REPORT BY SIR HENRY ROSCOE.

September 2nd, 1895.

Sir Henry Roscoe presented the following Report:—

"MANUFACTURING EFFLUENTS.

"With regard to manufacturers, the progress made has been of a satisfactory character. Much has been done, but much remains to be done. During the past eight months 256 samples of manufacturers' effluents have been analysed and reported upon. Of these forty were good and fifty-six were fair. In eighty-six cases the effluents were of an unsatisfactory character, and in seventy-four cases they were bad. In these latter cases, the attention of the manufacturer has been called to the condition of the effluent, and the response which as a rule has been given to these intimations was of a satisfactory character. I think the fact that only twenty-nine manufacturers have had to appear at a Local Government Board Inquiry, and of these only eleven have been prosecuted since the commencement of our proceedings, corroborates the opinion I expressed in my former reports, that the manufacturers had met the demands of the Joint Committee in a most conciliatory spirit.

"In order that the Committee may realise, to some extent, the importance of the work carried out by the manufacturers, I have had the following tables drawn up showing the condition of the effluent from works of different character, viz.: Bleachers and Calico Printers, Paper Makers, and Woolscouring Fullers and Felters, before and after treatment. A perusal of these figures proves that the work of purification can be carried out, and that considerable improvement in the condition of the streams has already been accomplished. I may say, shortly, that the main difficulty of solids in suspension had been obviated, and with regard to the soluble matter, especially that portion which produced pollution, the amount had been greatly reduced. I think the Committee might congratulate itself upon having done most satisfactory work with the help of the manufacturers. There was still work to be done, but the point was that they had shown that it could be done. As showing the value of the work of river purification which has been carried out as affecting manufacturers, I may mention that during the past few months I have had to deal with a matter of some importance, viz., the pollution of the River Medlock, caused by the Bradford sewer discharging sewage containing iron liquors from galvanising works. The discharge was not only objectionable as a polluting liquid, but was causing injury to various works situated below the outlet. Objection was taken to its admittance to the main drainage system of the Manchester Corporation on account of the chemical constituents of the liquid, and its large volume, which amounted to something like 576,000 gallons per diem. It was also feared that the admittance of such a liquid into the sewers would prejudicially affect the treatment of the sewage at the outfall works. The Corporation of Manchester, however, under my advice, connected this discharge with the main drainage, and the result has been satisfactory. One manufacturer told me that he had been benefited to the extent of being able to do work in two days which

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formerly took seven days to accomplish, and the saving in dye material and in not getting spoilt goods amounted to hundreds of pounds per annum. This expression of progress was also confirmed by a member of another large firm of manufacturers having works on the banks of the Medlock, and it is generally admitted that the condition of the Medlock is considerably improved. I may add that no evil results were found at the sewage outfall works, but, on the contrary, a decided advantage has been obtained, inasmuch as a saving of iron precipitant takes place when iron liquor comes down which is more than sufficient to treat the sewage flowing at the time.

"The question of manufacturers was a simple one compared with that of the Local Authorities. The difficulties in the latter case were very considerable. Since my report on this subject, presented on November 5th, 1894, some 120 additional tests on various samples of sewage effluents have been reported to the Committee in my monthly statements. I have not thought it necessary to plot out these results in the form of diagrams as formerly, but rather to call attention to a few important points which these analyses reveal, and to compare the position of affairs at the present moment with that of November 5th, 1894. First, with regard to the County Boroughs:—

"MANCHESTER.—Additional analyses since November 5th, 1894, have only lowered the average from 2·17 to 1·96, but it is satisfactory to observe that in the last month's return, August, 1895, the appearance of filtered effluents of high quality from this Authority, is evidence of the determination of the Corporation to meet the wishes of the Joint Committee, and of the probability of arriving at satisfactory results. Indeed, I may say that I am in good hopes that the ultimate result of the filtration of the whole of the effluent will be satisfactory to both Authorities.

"It has been said, and with truth, that 'The Mersey and Irwell Joint Committee Act' is a strictly prohibitive one as regards polluting liquids. It is, however, not enough to be able to show that *per se* a liquid is of a polluting character, for when legal proceedings have to be taken it is necessary to satisfy the Court whether the best available means have been adopted to prevent pollution, so that if this is shown not to be the case an Order may be obtained to compel the Authority to carry out efficient works. I have long felt that one of the unsatisfactory positions in which we are placed is that in the majority of cases we are unable to determine how far the various processes are efficient. The best indicator for showing the efficiency of the treatment is the percentage of impurity removed. This can, to a great extent, be judged of in the case of sewage treatment, by the proportion of organic matter removed to that originally present in the raw sewage, but this mode of measuring the amount of benefit received is less applicable to the effluents we have to deal with from manufacturing processes, where we have to calculate with constantly varying qualities of the materials to be treated, under widely different conditions. For the same reasons it is not advisable, in the case of manufacturing effluents, to fix any hard and fast standards of purity. With regard to sewage works, however, a limit of impurity has been drawn, the object being to guide the Joint Committee in taking legal proceedings, and to bring the more flagrant cases of pollution under notice. The object of sewage treatment on our watershed is not to transform the effluents into potable water, but to abate and finally to terminate the pollution of our rivers. The limit of impurity usually allowed in a drinking water is about one-twentieth of the limit of impurity which I have here adopted for sewage effluents, consequently the demands of the Joint Committee are reasonable, and in my opinion essential, if good results are to be obtained. In the large majority of cases of town sewage, chemical treatment is, as I have frequently remarked, not sufficient, some form of subsequent filtration being essential to obtain good results. This is fully borne out by the recent results from Manchester, to which reference has been made, where filtered effluents are obtained of high quality much below the fixed limits of impurity as shown in the diagrams, whilst the unfiltered effluent is above those limits.

"SALFORD.—Four additional results have been recorded showing no improvement.

"BOLTON.—No further results.

"ROCHDALE.—Two additional results have been recorded showing a marked deterioration in the quality of the effluent, 2·31 and 6·24 respectively.

"BURY, OLDHAM, AND STOCKPORT have not yet got sewage works in operation. The position of the County Boroughs, as regards the treatment of sewage, still remains, I regret to say, in an unsatisfactory position.

"NON-COUNTY BOROUGHS, 11.—Additional results from only one of these, namely, Hyde, have been obtained, and it has been necessary to prosecute this Authority for not using its filters and turning crude sewage into the river.

"URBAN SANITARY AUTHORITIES, 56.—Additional results from 29 of these Authorities have been recorded and the position remains nearly the same as in November last. Swinton and Pendlebury, also Whitefield, have been fined for pollution.

"RURAL SANITARY AUTHORITIES.—The additional results show generally a fairly satisfactory result, and two additional sewage works, Wardle and Northenden, have come into operation.

"*Resolved*—That the Report be received, and that the tables referred to in it be printed as an appendix to the proceedings.

CALICO PRINTING AND DYE WORKS.—TABLE A.

CRUDE EFFLUENT (Before Treatment). Grains per Gallon.						PURIFIED EFFLUENT (After Treatment). Grains per Gallon.					
Solids in Suspension.			Solids in Solution.			Solids in Suspension.			Solids in Solution.		
Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.
7·14	23·10	30·24	31·78	117·60	149·38	4·0	2·0	6·0	37·5	16·0	53·5
113·40	103·04	216·44	110·04	83·44	193·48	3·0	2·0	5·0	77·0	18·0	95·0
105·00	89·88	194·88	87·36	62·72	150·08	0·0	0·0	0·0	80·0	17·5	97·5
16·52	30·80	47·32	83·44	80·08	163·52	0·0	0·0	0·0	113·0	16·0	129·0
180·50	196·00	376·50	101·00	32·50	133·50	5·5	8·0	13·5	75·0	33·0	108·0
126·98	91·00	217·98	77·42	56·00	133·42	1·5	4·0	5·5	70·0	11·0	81·5
3·64	12·04	15·68	60·76	33·60	94·36	2·0	1·0	3·0	55·0	9·0	64·0
4·20	35·84	40·04	35·84	50·12	85·96	5·0	0·0	5·0	47·0	10·5	57·5
3·92	15·68	19·60	31·50	30·52	62·02	0·0	0·0	0·0	33·0	10·5	43·5
36·40	22·68	59·08	29·82	26·04	55·86	0·0	0·0	0·0	32·0	5·0	37·0
1·12	16·52	17·64	21·84	22·68	44·52	0·0	0·0	0·0	23·0	6·5	29·5
2·00	24·00	26·00	37·5	12·50	50·00	2·5	3·5	6·0	22·5	12·5	35·0

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For Sir HENRY ROSCOE.

BLEACHWORKS.—Table B.

Crude Effluent (Before Treatment). Grains per Gallon.						Purified Effluent (After Treatment). Grains per Gallon.					
Solids in Suspension.			Solids in Solution.			Solids in Suspension.			Solids in Solution.		
Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.
34·5	72·8	107·3	61·7	99·5	162·2	2·0	10·0	12·0	35·0	24·0	59·0
2·8	9·8	12·6	43·1	20·3	63·4	0·0	0·0	0·0	60·5	20·0	80·5
37·0	28·5	65·5	40·0	12·0	52·0	4·5	4·5	9·0	23·5	11·0	34·5
67·5	39·5	107·0	32·5	17·0	49·5	4·5	4·0	8·5	32·5	6·0	38·5
13·0	12·0	25·0	85·0	85·0	170·0	—	—	—	—	—	—
8·5	3·2	11·7	67·7	24·7	92·4	—	—	—	—	—	—
14·4	8·9	23·4	60·4	24·5	84·9	—	—	—	—	—	—
6·7	3·3	10·0	32·9	48·4	81·3	—	—	—	—	—	—
15·2	18·9	34·1	37·5	33·3	70·8	—	—	—	—	—	—
4·7	12·6	17·3	43·9	23·8	67·7	—	—	—	—	—	—
22·2	25·6	47·8	45·0	15·4	60·4	—	—	—	—	—	—
1·2	3·0	4·2	37·9	15·4	53·3	—	—	—	—	—	—
4·5	14·7	19·2	39·2	14·0	53·2	—	—	—	—	—	—
—	—	—	—	—	—	10·5	2·0	12·5	42·5	10·0	52·5
—	—	—	—	—	—	1·5	6·5	8·0	38·5	22·0	60·5
—	—	—	—	—	—	1·0	5·0	6·0	46·0	16·0	62·0
—	—	—	—	—	—	2·0	2·5	4·5	88·0	18·0	106·0
—	—	—	—	—	—	2·5	1·5	4·0	44·0	11·5	55·5
—	—	—	—	—	—	1·0	2·5	3·5	69·5	15·0	84·5
—	—	—	—	—	—	1·0	1·0	2·0	35·0	11·0	46·0
—	—	—	—	—	—	—	Trace	—	36·5	9·0	45·5
—	—	—	—	—	—	0·5	0·5	1·0	36·5	13·0	49·5
—	—	—	—	—	—	0·0	0·0	0·0	45·0	6·0	51·0

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WOOL SCOURING, FULLING, AND FELTING WORKS.—Table C.

Crude Effluent (Before Treatment). Grains per Gallon.						Purified Effluent (After Treatment). Grains per Gallon.						
Solids in Suspension.			Solids in Solution.			Solids in Suspension.			Solids in Solution.			Oxygen absorbed. (4 hours' Test).
Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	
45·64	94·92	140·5	546·0	667·8	1213·8	3·0	16·0	19·0	83·0	14·0	97·0	—
38·08	168·84	206·9	169·96	226·6	396·5	0·0	0·0	0·0	—	—	—	1·43
39·0	325·0	364·0	249·0	199·0	448·0	0·0	0·0	0·0	146·5	8·5	155·0	—
80·64	528·36	609·0	120·4	189·5	309·9	0·0	0·0	0·0	—	—	—	0·68
47·88	339·64	387·5	85·1	204·4	289·5	—	—	—	—	—	—	—
38·92	50·96	89·9	148·12	18·4	166·5	0·0	0·0	0·0	78·0	4·5	82·5	—
5·32	37·52	42·8	46·5	101·9	148·4	0·0	0·0	0·0	—	—	—	0·68 and 0·78
23·88	77·52	101·4	24·5	60·3	84·8	0·0	0·0	0·0	112·5	7·5	120·0	—
7·28	11·20	18·5	32·2	46·2	78·4	0·0	0·0	0·0	88·5	9·5	98·0	—
5·04	9·38	14·4	40·0	15·1	55·1	0·0	0·0	0·0	156·0	8·0	164·0	—
2·52	18·20	20·7	29·1	23·8	52·9	0·0	0·0	0·0	122·0	10·0	132·0	—
69·50	42·00	111·5	20·0	15·0	35·0	0·0	0·0	0·0	60·0	7·5	67·5	—
—	—	—	—	—	—	0·0	0·0	0·0	85·5	4·5	90·0	—
—	—	—	—	—	—	1·0	3·0	4·0	68·0	8·0	76·0	—
—	—	—	—	—	—	0·0	0·0	0·0	77·0	8·5	85·5	—
—	—	—	—	—	—	0·0	0·0	0·0	62·8	4·7	67·5	—
—	—	—	—	—	—	0·0	0·0	0·0	93·5	4·0	97·5	—
—	—	—	—	—	—	0·0	0·0	0·0	65·5	9·0	74·5	—
—	—	—	—	—	—	—	—	—	—	—	—	1·27

August 31st, 1895.

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For Sir Henry Roscoe.

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PAPER WORKS.—TABLE D.

CRUDE EFFLUENT (Before Treatment). Grains per Gallon.						PURIFIED EFFLUENT (After Treatment). Grains per Gallon.					
Solids in Suspension.			Solids in Solution.			Solids in Suspension.			Solids in Solution.		
Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.
50·96	49·08	100·04	86·80	53·20	140·0	19·0	16·5	35·5	81·0	50·0	131·0
33·04	55·16	88·20	51·80	38·64	90·4	12·5	2·0	14·5	84·0	34·0	118·0
36·40	72·24	108·64	30·52	15·40	45·9	3·8	14·7	18·5	47·0	11·3	58·3
49·84	34·72	84·56	190·40	55·72	246·1	—	—	—	—	—	—
131·60	14·00	145·60	117·60	98·00	215·6	—	—	—	—	—	—
27·00	45·00	72·00	266·00	169·00	435·0	—	—	—	—	—	—
32·30	59·00	91·30	170·00	48·00	218·0	—	—	—	—	—	—
43·50	53·50	97·00	206·00	155·00	361·0	—	—	—	—	—	—
75·88	42·00	117·88	105·28	55·16	160·4	—	—	—	—	—	—
31·50	38·00	69·50	93·00	41·00	134·0	—	—	—	—	—	—
31·80	22·30	54·10	83·80	22·70	106·5	—	—	—	—	—	—
23·52	29·68	53·20	55·44	31·36	86·8	—	—	—	—	—	—
10·80	3·00	13·80	51·80	32·40	84·2	—	—	—	—	—	—
—	—	—	—	—	—	4·0	5·0	9·0	98·5	25·0	123·5
—	—	—	—	—	—	0·0	0·0	0·0	59·4	46·6	106·0
—	—	—	—	—	—	0·0	0·0	0·0	67·0	15·0	82·0
—	—	—	—	—	—	5·5	8·0	13·5	48·0	15·5	63·5
—	—	—	—	—	—	6·0	3·0	9·0	32·5	15·5	48·0
—	—	—	—	—	—	2·5	5·5	8·0	23·0	5·0	28·0
—	—	—	—	—	—	1·0	4·5	5·5	15·0	9·0	24·0

August 31st, 1895.

FRANK SCUDDER,
For Sir HENRY ROSCOE.

This report deals with the progress which had been made up to that date and analyses of the crude liquors and the purified liquids from calico printing and dye works, bleach works, wool scouring, fulling, and felting works, and paper works are given. As showing the value of the work of river purification as affecting manufacturers, Sir Henry Roscoe refers to cases where manufacturers have reaped considerable benefit. Such instances might be enlarged, as, for instance, in paper works, where fibrous matter formerly allowed to escape into the rivers is now recovered and utilised; dye material from the colour shops, formerly ruthlessly thrown into the river; improvements in the composition of the dye liquors used in dye-becks; improvements in bleaching processes; the return of the manufacturer to the use of river water instead of town's water.

498. Have you made any special investigation of the effluent from fellmongers' works?—Yes. I desire to call the attention of the Committee to a report by Sir Henry Roscoe, dated November 26th, 1895, on the purification of fellmongers' effluents."

SPECIAL REPORT ON THE EFFLUENT FROM FELLMONGERS' WORKS.

"44, Mosley Street, Manchester,
"November 26th, 1895.

"Gentlemen,

"In my report to the Joint Committee, dated March 26th, 1892, I stated, with regard to this class of pollution, that, 'In this trade the waste products are very offensive. At present the whole of the foul liquors go direct into the streams, polluting the water for a considerable distance. Where sewers exist, the liquids, after subsidence, might be then got rid of. In other cases some method of purification, such as is used in the case of sewage, must be adopted.'

"In subsequent reports I have called attention to the serious character of the pollution caused by these works, and pointed out the necessity of treating the refuse discharge by chemical precipitation and subsequent filtration, stating that the effluent after chemcial treatment in tanks must be passed over land, as no amount of chemicals will produce an effluent which does not rapidly putrefy; and this is a point which must be strongly insisted upon, viz., that it is essential to have land treatment to produce a satisfactory effluent.

"Since the date of these reports all the works under the jurisdiction of the Joint Committee have been provided with tanks and cinder filters; precipitation with chemicals has been adopted, yet the effluents passing away after such treatment are still of an unsatisfactory character, inasmuch as they are found to contain too much soluble organic matter of a putrescent character. My assistant, Mr. Scudder, has examined a large number of treated effluents, and has also, from time to time, visited the purification plants in operation, and, as the results of his analyses and inspection, I have come to the conclusion that the filtering area in use in the several works under consideration is inadequate to effect a satisfactory result, and that a considerable extension of filtering area is necessary.

"I have had, through the courtesy of Messrs. Thomas Heap and Sons, of Haugh, New Hey, the advantages of making some experiments on the treatment of the refuse, and I find that the chemical treatment with alum cake, which all these works now adopt, can be more satisfactorily and economically replaced by the use of a mixture of lime and sulphate of iron. At the same time, the work which the filters are called upon to do would be relieved, and a more satisfactory result woud be attained.

"Of course, the filtration, whether it be by land or by porous material, must be intermittent, and the rate of flow so regulated that the filtering medium may remain active and capable of oxidising the organic matter in the water passed through the filters.

"Land treatment, where it can be applied, is the best; but where the difficulty of obtaining sufficient land arises, recourse must be had to artificial filtration through porous material.

"In order to compare the effect of the various precipitants, the amount of oxidisable organic matter, as measured by the oxygen absorbed, has been determined and taken as indicating the polluting character of the effluent.

"Thus we see from Table A that the untreated effluent absorbed 8·68 grains oxygen per gallon, whereas, after 2½ hours' subsidence, 6·51 grains oxygen were absorbed. In other words—

"1.—Subsidence alone removed 25 per cent. of the oxidisable organic matter.

"2.—After precipitation with alumina ferric cake at the rate of 3 lbs. per 1,000 gallons of effluent (costing 0·72d.), 51·2 per cent. of the oxidisable organic matter was removed.

"3.—With 1·42 lbs. lime and 4·288 lbs. copperas (costing 0·69d.) per 1,000 gallons, 63·7 per cent. of the oxidisable organic matter was removed.

"Smaller amounts of chemicals produce only very slightly better results than subsidence alone, and are, from a practical point of view, useless.

"It is, therefore, clear that precipitation with chemicals in the quantities as herein stated has only a limited action, and that it is essential to adopt, in addition, filtration. The effluent, ever after 63·7 per cent. of the objectionable matter has been removed, contains an amount of residual organic matter that will be a heavy burden to whatever filtering material it is passed through, and it is necessary that considerable filtering area and slow percolation of the effluent through the porous material should be adopted if satisfactory results are to be obtained.

Mr. F. Scudder, F.C.S., F.I.C.
12 July 1898

"I am, Gentlemen,
"Yours truly,
"HENRY E. ROSCOE."

"The Mersey and Irwell Joint Committee,
"44, Mosley Street, Manchester."

EXPERIMENTS ON THE CHEMICAL PRECIPITATION OF THE EFFLUENT FROM FELLMONGERS' WORKS.

No.	DESCRIPTION OF SAMPLE.	Oxidisable Organic Matter. Oxygen absorbed from Permanganate of Potash (4 hours' test). Grains per Gallon.	Cost of Chemicals per 1,000 Gallons in Pence.	Percentage of Oxidisable Organic Matter removed by subsidence + Chemicals = 100.
1	Untreated Effluent	8·68	—	—
2	After 2½ hours' subsidence	6·51	—	25·0
	Alumina Ferric Cake :—			
3	0·714 lb. per 1,000 gallons (at the rate of 5 grains per gallon).	6·43	0·17	25·0 + 1·2 = 26·2
4	1·42 lbs. per 1,000 gallons (at the rate of 5 grains per gallon).	6·41	0·34	25·0 + 1·5 = 26·5
5	2·14 lbs. per 1,000 gallons (at the rate of 5 grains per gallon).	6·37	0·51	25·0 + 2·1 = 27·1
6	3 lbs. per 1,000 gallons (at the rate of 21 grains per gallon).	4·80	0·72	25·0 + 26·2 = 51·2
	Copperas :—			
7	0·714 lb. lime + 0·714 lb. copperas per 1,000 gallons.	6·34	0·15	25·0 + 2·6 = 27·6
8	0·714 lb. lime + 1·42 lbs. copperas per 1,000 gallons.	6·24	0·25	25·0 + 4·1 = 29·1
9	0·714 lb. lime + 2·14 lbs. copperas per 1,000 gallons.	6·04	0·35	25·0 + 7·2 = 32·2
10	1·42 lbs. lime + 4·28 lbs. copperas per 1,000 gallons.	3·99	0·70	25·0 + 38·7 = 63·7

Alumina ferric cake, at £2 5s. per ton = 0·24d. per lb.
Copperas - - at £1 6s. „ = 0·14d. „
Lime - - - at 12s. „ = 0·064d. „

November 26th, 1895.

FRANK SCUDDER, F.I.C.,
For Sir HENRY ROSCOE.

499. What provision have the Fellmongers made for the purification of their waste liquors?—They have constructed settling tanks and filters. Precipitants are used.

500. What do you say as to the efficiency of these works?—They are inadequate to purify the large volume of waste waters. The area of filters are totally inadequate to deal with such a large volume, and considerable extension of area is necessary if good results are to be obtained. Moreover, the filtration, of whatever kind, must be intermittent, so as to allow of the complete oxidation of the organic matter.

FELLMONGERS.

TABLE showing: 1. The Filtering Area in Square Yards in use by each Manufacturer. 2. Number of Gallons Filtered per Square Yard per Day; and 3. The Estimated Volume of Water per Working Day treated.

Name of Firm.	Square Yards of Filtering Area.	Gallons per Square Yard per Day.	Volume of Water per Day treated in Gallons.
John Hill & Co. (Coptrod)	28½	1,412	40,000
Thos. Heap (Wood Mill)	56	625	35,000
Walter Heap & Co.	61	328	20,000
John Whitehead	91	unknown	unknown
Thos. Heap (Haugh)	158	215	34,000
William Clegg	456	548	250,000

FELLMONGERS.

TABLE showing: 1. The Tank Capacity in use by each Manufacturer. 2. Volume of Waste Water to be treated; and 3. Tank Accommodation expressed in Hours required to fill Tanks.

Name of Firm.	Tank Capacity in Gallons.	Volume of Waste Waters per 24 Hours.	Hours required to fill Tanks.
John Hill & Co. (Coptrod)	51,425	40,000	18½
Thos. Heap (Wood Mill)	14,000	35,000	9½
Walter Heap & Co. (Smallbridge).	10,049	20,000	12
John Whitehead	73,000	unknown	—
Thos. Heap (Haugh)	56,600	34,000	40
William Clegg	385,000	250,000	37

STANDARDS OF PURITY.

501. What is your opinion as regards the Royal Commissioners' Standards of 1868?—1. Royal Commission Standards of 1868. See Fouth Report, page 104. (*a*) Good effluents often do not comply with this standard, and, on the other hand, bad effluents containing soluble putrescible matter do sometimes comply with this standard. (*b*) Is not sufficiently stringent for sewage works, and too stringent for paper works, tanneries, and fellmongering works. (*c*) Is too severe a test, and not applicable to effluents from calico printing, dyeing, and

Mr. F. Scudder, F.C.S., F.I.C.
12 July 1898.

colour works. (*d*) Would not prevent river water being made unusable for manufacturing purposes. 1·4 grains Iron per gallon would render water unusable for dyeing purposes. 1·4 grains Iron is equivalent to 6⅔ grains Green Copperas (Crystallised Ferrous Sulphate). 1·4 grains Aluminium per gallon is equivalent to 8·8 grains Sulphate of Alumina ($Al_2(SO_4)_3$). Alumina ferric cake contains 51·1% $Al_2(SO_4)_3$, consequently 17·2 grains of Alumina ferric cake would be allowed to escape under this standard (*e*) A desirable standard on account of the poisonous character of arsenic. (*f*) An applicable standard. (*g*) An applicable standard. (*h and i*) Have been inserted entirely in the interest of fish. (*k*) Is of value so far as it goes, but it does not provide a remedy against pollution from pyroligneous acid, charcoal, and gas works.

MANUFACTURING EFFLUENTS.

502. What is your opinion as to the advisability of adopting Standards?—(1) Definite standards not desirable. (2) The best practicable and available means to be insisted upon for the treatment of foul liquids escaping from any factory. (3) Each case to be treated separately on its own merits. (4) The manufacturer is fully protected from "vexatious litigation" by the course pursued by the Mersey and Irwell Joint Committee, viz.:—1st. By calling the manufacturer before the Committee to show cause why proceedings should not be taken against him. 2nd. By the intervention of the Local Government Board, who hold a local inquiry into the merits of the case, and decide whether or not proceedings in a court of law should be instituted. (5) The manufacturer, when he appears before the Joint Committee to show cause why proceedings should not be taken against him, is told in definite terms what is objected to and what is required of him.

503. Is it desirable in your opinion to extend the provisions of the Pollution Prevention Bill?—Undoubtedly similar requirements to those which are exacted in the Mersey and Irwell Watershed ought to be exacted all over the country. Manufacturing interests demand this. There have been 39 applications to the Local Government Board on behalf of the Mersey and Irwell Joint Committee to take proceedings against the manufacturer for pollution —1893 to June, 1898. These applications may be classed as follows:—

CLASS OF POLLUTION.

Calico Printing and Dyeing Works ...	16 Cases.
Bleach Works	6 ,,
Woollen Works	5 ,,
Fellmongers' Works	4 ,,
Paper Works	3 ,,
Brewers	2 ,,
Waste Bleachers	2 ,,
Colour Manufacturing Works	1 ,,
	39

504. Have you made any analyses of sewage effluents?—With regard to the effluents from the treatment of sewage from the various sewage works under the jurisdiction of the Mersey and Irwell Joint Committee, I have analysed the whole of the samples, the results of which have been presented to you in the form of diagrams by Mr. Tatton.

505. What conclusions do you draw from these results?—It is clear from a consideration of these results that filtration of some kind is essential for the efficient purification of sewage. Sir Henry Roscoe, in a report dated October 31st, 1894, reviewed the results of such determinations, and for the purpose of criticising and comparing the results in these particular cases certain standards were adopted. I hand in the report referred to. The limits of impurity were fixed at 1-10th grain per gallon albuminoid ammonia, ¼ grain oxygen absorbed 3 minutes' test; 1 grain oxygen absorbed 4 hours' test. These limits of impurity have been of great value for the purposes of classifying the purity of sewage effluents. Great dissatisfaction has been expressed by many with regard to these standards, especially by those who have been in the position of being responsible for the efficient purification of sewage, and instead of standards being what the Royal Commissioners of 1868 considered "real friends" to the Sanitary Authorities, they have been a great bone of contention. Nevertheless, I believe that the following table dispels the suggestion that the Mersey and Irwell Joint Committee have taken an impracticable attitude on the question of standard of purity or that they have adopted excessive requirements as to purity:—

PERMANGANATE TEST, FOUR HOURS.—Results of the examination of sewage effluents submitted by the Mersey and Irwell Joint Committee. January to December, 1897, from 54 Sanitary Authorities representing a population of 1,684,002.

	—	Per-centage.
Effluents classed as good and fair -	220	71·7
,, ,, unsatisfactory -	47	15·3
,, ,, bad - - -	40	13·0
Total tests - - -	307	100·0

Effluents that absorbed oxygen from—

0·07 up to 1 grain per gallon	211	
1·0 grains to 1·25 grains per gallon ...	21	
1·25 ,, 1·50 ,, ,, ...	10	
1·5 ,, 2·0 ,, ,, ...	14	
2·0 ,, 2·5 ,, ,, ...	14	
2·5 ,, 3·0 ,, ,, ...	8	
3·0 and upwards	29	
	307	

Good and fair effluents—

From precipitation alone	7*	
,, filtration	213	
	—	220

Unsatisfactory effluents—

From precipitation alone	16	
,, filtration	31	
	—	47

Bad effluents—

From precipitation alone	34	
,, filtration	6	
	—	40
Total		307

*Oldham.....	0·63 grain and 1·0 grain per gallon...		2
Rochdale	0·82 ,, 1·0 ,,	...	2
Milnrow ...	0·63 ,,	...	1
Prestwich...	1·00 ,,	...	1
Kearsley ...	0·52 ,,	...	1
	Total		7

ANALYSIS OF THE "BAD" EFFLUENTS. 40 SAMPLES.

From precipitation alone. 34 Samples...

*Manchester, oxygen absorbed 3·56 to 6·45 (average 4·93)	12	
*Salford, oxygen absorbed 2·06 to 4·60 (average 2·95)	13	
Hyde ,, ,, 2·1, 2·53, and 6·03 ...	3	
*Bolton ,, ,, 4·47 and 5·97 ...	2	
*Rochdale ,, ,, 6·84	1	
Gorton ,, ,, 3·0	1	
Kearsley ,, ,, 3·44...	1	
Castleton ,, ,, 2·92...	1	
		34

*County Boroughs.

From filtration. 6 Samples...

Timperley, oxygen absorbed 2·65 and 3·19 ...	2	
Droylsden ,, ,, 3·37	1	
Rochdale ,, ,, 2·10	1	
Radcliffe ,, ,, 2·42	1	
Altrincham ,, ,, 2·71	1	
		6
		40

From these sewage works which used filtration, the following results have been obtained during the past year:—

Timperley, oxygen absorbed	0·76, 0·74, 0·51, 0·58, 0·38.
Droylsden ,, ,,	0·65.
Rochdale ,, ,,	0·82, 1·00.
Radcliffe ,, ,,	0·41, 0·11, 0·41, 0·47.
Altrincham ,, ,,	0·49, 0·66, 1·24, 0·89.

If we exclude the samples from the County Boroughs, viz., 28, we get—

		Percentage.
Good and fair	220	78·9
Unsatisfactory	47	16·8
Bad...	12	4·3
	279	... 100·0

Population of 763,602.

Moreover, these results show that the 1 grain oxygen absorbed 4 hours' test standard is only used for the purposes of classification, and not as a definite standard. For instance, it is observed that it is most difficult for a precipitated effluent to get within the standard, and on the other hand, where efficient filtration has been carried out, the results are considerably below the standard. With regard to filtration, Sir Henry Roscoe reported to the Joint Committee on May 26th, 1897. That report I hand in.

REPORT ON ARTIFICIAL FILTRATION.

"10, Bramham Gardens,
"Wetherby Road, S.W.,
"May 26th, 1897.

"To the Consulting Sub-Committee.

"GENTLEMEN,

"I have pleasure in reporting to your Committee as to the efficiency of the results obtained in the treatment of sewage by precipitation and artificial filtration.

"I am of opinion that the adoption of artificial filters is a move in the right direction, especially in the case of large towns having difficulties in acquiring sufficient area of land and of a suitable character for the purification of its sewage.

"Land filtration, so far as the chemical results are concerned, is superior to artificial filtration. Unfortunately, however, the volume of effluent that can be treated permanently on land is small as compared with the volume that can be filtered by artificial filters.

"I have had the advantage of carrying out important trials, extending over a period of 17 months, with filters made both of cinders and of coke for the Rivers Committee of the Manchester Corporation, and the results have been of a satisfactory character. The effluent submitted to filtration had previously been treated with milk of lime and copperas. The volume of such effluent, which an acre of filter was able to deal with continuously, was about 800,000 gallons per day. It remains, however, to ascertain how long these filters will work satisfactorily before requiring renewal of a part or the whole of their contents, and this is a cardinal point.

"Artificial filters have, in some instances, been adopted at sewage works under the jurisdiction of your Committee, and the failures which have frequently attended their use are traceable to the non-compliance with the conditions which are essential for successful and permanent purification. Quoting from my report to the Rivers Committee of the Manchester Corporation, dated April, 1896, I said:—'The conditions essential for successful purification by filtration, viz., the conversion of the organic carbon and of the organic nitrogen in the sewage into inorganic matter, have long been recognised and advocated, but, I am sorry to add, generally ignored in practice.'

"The Rivers Pollution Commission, 26 years ago, pointed out that in filtration, whether through sand, gravel, chalk, or soil, or a mixture of chalk and sand, it was essential that the atmospheric oxygen should have frequent and free access to the interior of the filter, and that the effluent should flow freely off from the bottom of the filter, so that as the last portion of each dose of sewage water sinks into the filter it may draw atmospheric air into the pores of the material from the surface downwards. The subsequent researches of Messrs. Müntz and Schloesing in France, and of Professor Warington in this country, have shown that purification, as defined above, is brought about by the intervention of micro-organisms. Professor Warington has also pointed out (14 years ago) that sewage contains the micro-organisms necessary for its own destruction, and that, under favourable conditions, these may be so cultivated as to effect the purpose, provided the filter is well supplied with air requisite for the discharge of their functions, and also that sufficient lime be present to combine with the nitric acid, otherwise the process of nitrification is stopped. The results of the experiments made by the American chemists (1891) of the Massachusetts Board of Health confirm the above statements, for they state that—'The purification of sewage by intermittent filtration depends upon 'oxygen and time; all other conditions are secondary. 'Temperature has only a minor influence: the organisms 'necessary for purification are sure to establish themselves 'in a filter before it has long been in use. Imperfect purification for any considerable period can invariably be 'traced either to a lack of oxygen in the pores of the filter, 'or to the sewage passing so quickly through that there is 'not sufficient time for the oxidation processes to take 'place. Any treatment which keeps all particles of 'sewage distributed over the surface of sand particles, in 'contact with an excess of air for a sufficient time, is sure 'to give a well oxidised effluent, and the power of any 'material to purify sewage depends almost entirely upon 'its ability to hold the sewage in contact with air. It must 'hold both sewage and air in sufficient amounts. Both 'of these qualities depend upon the physical characteristics 'of the material. The ability of a sand to purify sewage, 'and also the treatment required for the best results, bear 'a very close relation to its mechanical composition.'

"The difficulty of the subject lies not of course with the smaller authorities. Thus out of 54 Sanitary Authorities reported upon this month, 37 are satisfactory; and all of these, with the exception of Oldham, which is not completely connected up, are small ones; and in these, land filtration (16 cases), or artificial filtration (19 cases), or tank precipitation alone (2 cases), have yielded a satisfactory result. It is where we have to deal with large populations that the difficulty becomes great, because the data upon which conclusions as to the practical and permanent efficiency of artificial filtration on a large scale is yet wanting. To obtain such data, I advised the Rivers Committee of the Manchester Corporation to carry out artificial filtration on a considerably larger scale than had hitherto been the case.

"HENRY E. ROSCOE.

"Mersey and Irwell Joint Committee,
"44, Mosley Street, Manchester."

Mr. P Scudder, F.C.S., F.I.C. 12 July 1898.

Artificial filters are a move in the right direction, especially in the case of large towns having difficulties in acquiring sufficient area of land, and of a suitable character for the purification of its sewage. Manchester and Salford are instances where artificial filters might be adopted with advantageous and satisfactory results. So far as chemical results are concerned, land filtration is superior to artificial filtration. Instance: Stretford, Alderley, and Wilmslow.

506. In Sir Henry Roscoe's report on "Manufactory Effluents," it says, "One manufacturer told me that he had been benefited to the extent of being able to do work in two days which formerly took seven days to accomplish, and the saving in dye material and in not getting spoilt goods amounted to hundreds of pounds per annum." I was not quite clear what the meaning of that was—I mean, how would that benefit arise?—It arose in this way. This manufacturer was situated below the outfall of this iron liquor into the stream. He was only able to draw water at periods when this iron liquor was not falling into the stream, but by its removal he had water at command at any time of the day. Now, sometimes during the day there would be no iron liquor coming down, and when he opened the valves to take the water into his reservoir, before he got any amount of water accumulated this iron liquor would commence to come down and pollute the water which he was using for the purposes of logwood dyeing.

507. This benefit came to him from getting the water unpolluted?—Quite so, and getting water which was practically pure water free from soluble iron.

508. Then you say "that no evil results were found at the sewage outfall works, but, on the contrary, a decided advantage has been obtained, inasmuch as a saving of iron precipitate takes place when iron liquor comes down, which is more than sufficient to treat the sewage flowing at the time." What does that mean?—At the time this discharge was disconnected from the Bradford sewer and coupled with the main drainage I was in charge of the sewage works at Manchester, and this iron liquor came down to the outfall works for about three hours a day. During those three hours we had not to use any copperas, but used this iron liquor for purposes of iron precipitation; consequently we saved so much copperas. Then at a later period Sir Henry Roscoe suggested—we had no idea really, at least

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we did not anticipate that there was such a large flow of this liquor as there turned out to be—and he suggested it might be desirable to put down a tank at the Corporation's expense at the works of the Galvaniser, and to distribute the liquor over a longer period, so that instead of getting only three hours precipitation we could get as much liquor as would precipitate for eight or nine hours a day. So that this was an instance where the manufacturing waste was most difficult to satisfactorily deal with in order to bring the river into a condition for the water to be suitable for another manufacturer, but the liquor was of great use to the Corporation to take into their sewers, because it acted as a precipitant upon the sewage.

509. You removed it from where it was doing harm to where it was doing good?—Yes, that is the fact.

510. Then the next thing I wanted to ask you was about the Massachusetts Board of Health. May I ask whether of your own knowledge you can express any original opinion about them?—Well, I have not had the advantage of going over to America to see these particular filters, but I have had the advantage of meeting the principal chemists who have been engaged in this work, through Sir Henry Roscoe. Professor Drowne, for instance, who took an interest in this work, came over to London, and I have had interviews and seen the result of his work. I have followed it very closely, and have great confidence, and believe thoroughly in the results which they have published. I think they are truly scientific and perfectly reliable and accurate, and from my own experience in similar work I corroborate what they say.

511-512. And do you know whether the Americans are availing themselves of those results?—Well, they have made some progress.

513. They have?—Yes. There is a very good series of articles on the application of this work to practice by Professor Ronna. I have not got the volumes with me, but I can get them, and give you the reference to that French expert who went over there, and not only saw these experimental filter-beds, but went to where the system has been applied to town sewage.

514. (*Dr. Russell.*) Is Professor Ronna an American?—No, a Frenchman.

515. (*Chairman.*) You say, "So far as chemical results are concerned, land filtration is superior to artificial filtration." You feel clear about that?—Oh, yes; I think there is no doubt about that. But I should like to explain a little more extensively my meaning. If you have ten gallons of sewage to purify, there is no doubt the most efficient way to purify that ten gallons is by filtration through land.

516. Yes?—It gives the best result. But you can also purify that 10 gallons through artificial filters, but in no case of artificial filtration can you get results equal to those produced by land. When you come to reflect it is very easily seen why. The land filter is more compact, it holds the sewage, but will not allow it to go through rapidly. The consequence is that by slow percolation it gets into the conditions which the Massachusetts Board of Health and chemists have shown to be essential for efficient filtration. The land is almost like a carriage with a brake upon it. You cannot force it through; it will stop before it will fail, consequently land is preferable to artificial filters.

517. You told us a small quantity—ten gallons; do you say the same of any quantity?—Of course, but then the point is that when you get a large quantity you want such a tremendous area of land.

518. Yes?—And then it becomes a question whether it is not better to adopt artificial filtration, and on considering that we have now got a great development of the theories, or, rather, we have got now to know the conditions and the reasons why purification is brought about, I think artificial filtration may be safely adopted, provided it is worked according to suitable conditions, intermittency being a vital condition for efficient results.

519. But you would still say that provided there was enough land that system would be superior to any artificial filtration?—I think that is so. I may point out, for instance, I will take the case of Stretford, which is shown on that diagram. (*Pointing to diagram hanging on the wall.*) Stretford is a place where land filtration is resorted to; the results are invariably good; they are considerably below that limit of impurity which we have thought it advisable to fix for the purposes of classifying effluents. I have never in my experience of artificial filtration been able to obtain similar results. It was suggested at the onset, when artificial filtration got a great move on, and got attention attracted to it by Mr. Dibdin's researches—Mr. Dibdin said the longer effluent water was kept in contact with the filtering material the better was the result. It has been proved that that is not so; that it is not improved by keeping. There is a certain time allowed, during which certain purification is effected; beyond that you cannot go. In other words, by artificial filtration, I mean, biological filtration, you cannot produce an effluent so pure as you can by land treatment. When you come to consider artificial filtration without the intervention of organisms, as in the Polarite system you get an effluent of almost the same degree of purity as land effluent, but there are objections to that system which we shall have probably to discuss before I leave.

Appendix No. 10.

520. (*Mr. Killick.*) You speak of the "limits of impurity." Would you inform the Commission what these are, and why they were fixed?—Sir Henry Roscoe, in his capacity as adviser to the Mersey and Irwell Committee, was asked to analyse and report monthly on the quality of the effluents which were produced from the sewage works under the authority of the Mersey and Irwell Committee. In order to do so it was necessary that we should classify those effluents so as to guide the Committee—all the members of which are not chemists—in judging of the merits of the effluents from the various works. We decided after experiments that we should have three strings, as it were, to our bow, that we should not rely upon one method of analysis alone, that we should take the amount of putrescible organic nitrogen as measured by albuminoid ammonia, fixing a limit of ·1 grain per gallon; also that we should use the pergmanganate test with the three minute test to show the putrescible matter by absorption, and also the four hours' test. Those three results were sufficient for us to classify those effluents into good, fair, and bad. They were not standards, and in that report where Sir Henry Roscoe discusses this question, in the report of October 31st, he laid before the Committee a number of analyses showing how these limits could be obtained from works which involved filtration. There was actually no difficulty in getting below that limit, and it was in order that the Joint Committee might put on one side effluents which we might pass for the time being until we got the others into line with it—that is, works that did not recognise filtration as essential. It was necessary to prepare diagrams, and diagrams were prepared as early as 1894, the same as those *there* (*indicating diagrams on the wall*), and it was very clear that the Committee were able to deal with it, and authorities understood very well from a diagram like that that precipitation alone was not sufficient, and that they must carry on filtration. It was not really a definite standard; but, unfortunately, the sanitary authorities have looked upon it rather as a standard, and raised strong objections to the fixing of the standard, especially in the cases of Manchester and Salford; they did not think it was possible to get an effluent where the oxygen consumed would be less than one grain per gallon. As soon as ever they got land filtration into operation, however, they obtained very often very much below that one grain, more like '5, and when they got artificial filtration they found no difficulty in getting below the limit. And that limit of impurity, I may say, was fixed from experiments which we made, distinguishing on the one side effluents which became putrid on standing, from those which did not become putrid. It was a sufficient division line to guide the Committee in their work of purification, and we did not wish to set up an ideal or theoretical standard; we did not even suggest that they should have nitrates in the effluent which are very important to take into account when judging of the quality of an effluent. We simply wanted to guide the Committee in their practical work.

521. It is the lowest standard we possibly could take?—That is so.

522. Professor Ramsay will probably inquire from Mr. Scudder about that

(*Professor Ramsay.*) Yes.

523. (*Colonel Harding.*) I think I understood Mr. Tatton to say that for the present your Board did no call upon manufacturers to do more than withdraw the solids from their effluents?—Yes; Mr. Tatton said so.

524. In certain cases, as, for instance, the effluents from tanneries, you have after the withdrawal of the solids an effluent which is confessedly very foul?—That is so.

525. May I ask you as a matter of fact whether you can induce the manufacturers to further purify that liquid effluent?—Oh yes, we have powers for that.

526. I rather gathered that nothing further was claimed of them?—I should rather like—well, not to modify Mr. Tatton's statement, but Mr. Tatton did not go quite far enough. Mr. Tatton said that we were contented with the removal of the solids in suspension. That is so. The first

thing that is said to the manufacturer when he appears before us is, "We want the solids in suspension removed," and the Joint Committee have contented themselves with resting upon that. But what does it mean? Take any manufacturer's effluent. If he removes the solids in suspension he at the same time has to remove a portion of the solids in solution which is liable to separate out on standing. Therefore, when we insist upon having effluents freed from suspended solids we at the same time gain the removal of objectionable matter that is in solution. And that applies equally to all the classes of effluent except the cases of fellmongers. A calico printer has a liquid which has ten grains of solids in suspension. He is called upon to remove that simply; subsidence does not remove it, he has to resort to precipitation. He not only removes the ten grains of solids in suspension, but he removes some of the soluble matter which it is necessary to remove. So that in judging of an effluent as a chemist I judge it not only by the solids in suspension, but by the solids in solution, especially those that are liable to settle out on standing. But for all practical purposes Mr. Tatton was quite right in his reply. If a manufacturer removes his solids in suspension he is bound to remove a good deal of that which is objectionable in solution at the same time.

527. Probably it would be ultimately necessary to remove other organic matters in solution?—Yes. I have called special attention to the case of fellmongers. Fellmongers—there are not many of them under the jurisdiction of the Mersey and Irwell Committee, but they have on the whole spent a great deal of money in putting down tanks for the removal of the solid matter. They all use a precipitant, and I have given in this paper the size of the tanks, the number of hours it takes to fill these tanks, and I have also given the filtration area. If you compare the filtration area in each case, it is on the face of it certain that the filtration area is inadequate to meet the requirements that we want. A fellmonger's refuse is practically concentrated sewage, and the area that each of these manufacturers have put into operation is really too small. We want to be in a position of pressing them to extend this area; they will have to have considerably larger filter areas; there are very few of them cannot do it.

528. Have you any instances where fellmongers' or tanneries' effluent is dealt with on the intermittent filtration plan?—No. We have now advised the fellmongers to try filtration on the intermittent plan. If it is not worked on the intermittent plan they will never get efficient results.

529. But you think that with the system of intermittency they probably will get improved results?—Yes.

530 And get rid of much of the organic matter in solution?—Yes, and the fellmongers have promised to try this. A fellmonger works ten hours a day; during that time he passes the effluent through his tanks, and the whole of that must go through filtration. They have only adopted mechanical filtration because they have not appreciated what intermittent filtration means.

531. To some extent it may be considered that the action taken by your Board is an interference with trade, but on the other hand you would agree with me probably that the purification of the streams would be a very great facility to trade?—Yes, that is so; I think it is admitted by manufacturers.

532. This advantage on the one hand would greatly compensate the disadvantage on the other?—Yes.

533. Reference has been made by Lord Iddesleigh to the Massachusetts' experiments. I think you said you had to some extent confirmed them by experiments of your own?—Yes.

534. Laboratory experiments?—No; experiments both carried out on experimental works, and applied practically.

535. Those would be of great interest to us. Are there any works at present being carried out upon that plan within your district?—How I came to carry out the experiments by biological filtration was acting under Sir Henry Roscoe as adviser to the Manchester Corporation.

536. At Manchester some experiments are now being carried out on biological grounds?—We commenced our experiments in Manchester on biological grounds in November, 1895. We had suggested in the early part of 1895 that it was necessary that we should attempt to deal with the soluble putrescible organic matter in the tank effluent from the sewage works.

537. Have you been doing that continuously since 1895?—December, 1895. I put down from my own drawings two filter-beds, 25 square yards each in area, to deal with the sewage on biological grounds. These filter beds were under my own personal observations and government for at least eighteen months, during which time they worked satisfactorily. They were then handed over to a chemist in whom we have every confidence, appointed by the Corporation, and he has continued to work them with good results up to the present moment, and they are now going on.

538. In that case what is it you are dealing with; is it the effluent from chemical precipitation?—Yes.

539. No crude sewage?—By treatment with lime and copperas, not crude sewage.

540. How is it being dealt with, what amount of rest is given, what are the cycles of working, do you fill six or three times a day?—Three times a day.

541. Are they cycles of eight hours—they must be?—No; we are working—I have got full particulars, I have everything worked out, I have got——

542. Without taking up time too much, the principle is that you allow an adequate time, and you find that through these filters you get good results?—Yes.

543. And do you find that the filters will work continuously without the material being changed?—That was the object of the experiments, to see what was the life of the filter.

544. What is your experience in regard to that point?—My opinion is that the filter will go on for an indefinite time. We have had them from November, 1895, up to the present time working satisfactorily, and nothing has been done to the filter.

545. You said 1895; I suppose it is really 1896; it was December, 1895, did you not say?—Yes.

546. Then really it is 1896-97, two years?—Yes. They are still going to-day—the same filters; they have never had the material taken out of the filter, and they are purifying the same quantity of tank effluent.

547. You say they are purifying the same quantity of sewage; has that been actually tested?—Yes; I have tested it myself.

548. There has been no accumulation of matter in the filters?—There has been an accumulation. During the first year of working I think the capacity of the filters deteriorated 10 per cent.; after that they did not deteriorate at all. But in those two filters we have never gone beyond an area of filtration equivalent to 800,000 gallons per acre. That applies of course to Manchester. The Manchester effluent treated in the way in which they treat it can be satisfactorily purified if the volume is not greater than 800,000 gallons per acre. Of course, it varies in different places.

549. In Manchester sewage do you find great variety of trade effluents?—Yes.

550. Are any of them of an antiseptic character?—Yes.

551. A good deal of iron liquor?—Yes, and also from tar works, and so on, and dye works, you know. Practically you may call it manufacturing sewage, but, notwithstanding that sewage, there is very little sewage proper in Manchester.

552. You mean trade effluents are much more serious in their volume?—Yes.

553. Then you alluded to Professor Ronna, and told us that he had practically applied the system somewhere—you did not tell us where?—No. He had visited the States where the experiments of Massachusetts had been practically applied to the treatment of town sewage.

554. You do not know any places where they are practically applied?—I have not got the papers with me.

555. You have told us that it was your strong opinion that artificial filters could not bring about such good results as land filtration?—That is so.

556. But probably you would allow that our experience of filtration on biological lines has not yet gone very far?—That is so, but at the same time I cannot lose sight of the fact that if you get a land filter it is so compact you are bound to get a good effluent, because you cannot get the volume through. On the other hand with a biological filter you can get any volume through, and in that respect we must take care that it is worked on scientific grounds.

557. But assuming a biological filter is worked on scientific grounds, and that the amount of sewage put upon it is strictly limited to what it should be, and that you have an adequate area so as to have not only duplicate but it may be triplicate filtration; do you say that even then it would not be possible for artificial filtration to obtain as good results as are obtained by land filtration?—Yes, I do.

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558. Then you have told us in regard to your standard that it was in effect that the effluent should not become putrid on standing?—Yes.

559. How do you test that; do you keep it in open vessels?—No; in a closed vessel at a temperature of 75 degrees Fahr., under conditions favourable to putrefaction, and it is left for five days. The way we test them has never been published in the Proceedings of the Mersey and Irwell Joint Committee, but what we do is this: we take the three minutes' observation, the permanganate test, on receipt of the sample. Then the sample is put into a stoppered bottle at a temperature of 75 degrees for five days; after that the three minutes' test is applied, and if the sample has gone bad at all, if there is any putrescence, if the oxygen absorbed has increased, you are able to give figures to what has previously been only described as a smell, and so on. Some chemists get so accustomed to sewage effluents that they cannot smell one when it is bad. I can show you diagrams setting forth the results obtained.

560. Do you find that effluents which are below the limit of one grain per gallon of oxygen absorbed in four hours can be relied upon not to turn putrid on standing?—That is so. I should just like to show that by a diagram I have here with regard to the filter beds which I have referred to at Manchester during the period from March 8th to March 14th. The average results of the tanks' effluent going on the filter on the receipt of sample is shown by *that* column there, pink (*indicating on diagram*), up to *there*. Then the sample after it has been in the incubator it had risen to *that* point; that shows the measure of the putrescibility of the tank effluent. After it has gone through the cinder filter, instead of going bad, instead of the oxygen consumed going up it has really purified itself, and it has come down *that* much; the purple shows that. The coke has also come down from *that* point to *that*, and that is the limit of impurity allowed.

Appendix No. 11.

561. (*Chairman.*) You said you had some details of your experiments at Manchester that you could hand in; would not they be very interesting?

561 *. (*Mr. Killick.*) They would be very valuable?—I have got the whole of the details in my reports.

562. The difficulty is that in many of these cases one cannot get these experiments carried out on scientific lines, and if Mr. Scudder has done that, as I am quite sure he has if he has had anything to do with it, those results would be very valuable to us?—I may add this: I have been talking over the matter with Sir Henry Roscoe, and we thought it would perhaps be better to-day that we should confine ourselves to the work which we have done for the Mersey and Irwell Joint Committee. I may say that this work has been done outside the Mersey and Irwell Joint Committee.

563. (*Chairman.*) These experiments you have mentioned?—These experiments I have mentioned, and Sir Henry Roscoe thought, if you would like it, that at some later period I could come forward with the results of the Manchester experiments and other experiments I have made. I have applied the knowledge we have gained at Manchester to the treatment of sewage on a large scale.

(*Colonel Harding.*) I am quite prepared to postpone any further questions dealing with the Manchester experiments.

563*. *Dr. Russell.*) With regard to artificial filtration and land filtration, you characterise artificial filtration as biological?—That is so, as carried out at Manchester.

564. Is not land filtration distinctly biological?—The same thing governs it, and that is why I want to maintain that land filtration is bound to give the better effluent.

565. The filter in the one case is made by nature, and in the other it is made by man?—From the Mersey and Irwell point of view land is preferable if you can only get the necessary area of land, for this reason, that if you have your effluent you cannot push it through the land, but, on the other hand, if you have these artificial filters where they are made very open—the more open the filter is the less purification you get.

566. That seems to point to the desirability of improving the conditions of artificial filtration if possible?—That is so, and that is why I think we must not look forward to being able to purify very large volumes. It is a great jump—for instance, if you take land filtration, take it at 60,000 gallons to the acre, I do not suppose there is any tank effluent in the kingdom which would pass more than 60,000 gallons through fairly good soil. The jump from that 60,000 gallons to 800,000 gallons is tremendous. Of course, these experiments have been conducted by us as chemists on an experimental scale. What they would really do on a large scale time alone will show. But it would be better not to allow over the maximum amount that is possible. I do not think you will find in the course of time that a million gallons of any effluent can be treated on an acre of artificial filter. No doubt half a million goes exceedingly well, and will go for a number of years, but if they were to increase the volume to a million gallons they would not get the same purification.

567. Still the practical result encourages one in cases which exist, where the area of land for filtration is enormous as compared with artificial filtration, to endeavour to improve and ascertain the conditions under which you can get the largest amount and the best quality of work out of artificial filtration?—That is so. The Royal Commission of 1868 were within an ace of finding out—they did find out—the conditions for efficient filtration, but the only point they missed was the action of the organisms. They found out all the conditions; they even went to the length of finding the advisability of having a lime present to combine with the nitric acid formed. There is a special remark in the report of the Royal Commissioners which I think is worth calling the attention of the Commissioners to, because it emphasises what I impress upon this Committee, that the land gives better effluents than artificial filtration. They say that an acre of soil three or four feet deep must be far superior for dealing with the sewage of 100 people to any filter that can be practically worked for this purpose. That is an ideal. If you could get land and put the sewage of 100 people over it that would be the ideal result.

568. (*Mr. Cotton.*) I wish to ask you whether artificial filtration with a small amount of land filtration afterwards could not be made equal to the best land filtration—to the result of the best land filtration. You say that artificial filtration could never be equal to land filtration?—That is so.

569. But could not artificial filtration with a moderate amount of land filtration afterwards be nearly equal at any rate?—Of course you come to the question, What do you mean by a "moderate amount" of land filtration.

570. Depending upon the quality of the effluent from the filtration?—It does not depend so much upon the quality of the effluent; it depends more upon the quantity, the volume of effluent. You take the volume of Manchester sewage, and take really the excremental matter, the organic animal matter, it is very small in comparison to the total pollution, and when you have got a large volume of polluted water to filter through land, there is such a great tendency for dissolved oxygen to disappear that you close or render useless the pores of the land. Therefore, I do not at all sympathise with any attempt to try biological filtration with subsequent land filtration.

571. Afterwards?—Afterwards.

572. (*Professor Foster.*) You heard my question to Mr. Tatton with reference to the different kinds of systems adopted within the area?—Yes.

573. Can you in addition help us to those which you think are the most typical of the different kinds of systems?—Yes; I think so.

574. If so, we might choose one or another?—I think I would rather say that with regard to biological filtration I do not think there is very much evidence to go upon in our watershed. You have, for instance, the experimental filter beds at Manchester, of which I shall be very pleased to give you the very latest results up to date. You can go over them. I can show where it has been applied to the treatment of some 1,500 gallons per day. Then, too, I can take you where we have put down filter beds that are dealing with half a million gallons a day—at the Swinton Sewage Works, on two cinder filters, a quarter of an acre each in area, and we are collecting the results. I have got with me now the whole of the results from the cinder filter beds, which have been in operation for 18 months. But this is work independent of the Joint Committee.

575. (*Colonel Harding.*) It would suffice for the present if Mr. Scudder would just indicate where experiments of this kind are being carried on in the area of the Mersey and Irwell Board, and then we could make special inquiry as to them?—At the Pendlebury Sewage Works I have there not only carried out artificial filtration, but we are now putting down a tank containing filtering material to purify raw sewage direct by filtration or by contact with solid material, that is, without the removal of the sludge. Those are all experiments which are in progress; they are not in a condition to report upon from the Mersey and Irwell point of view.

576. Will you give us a list of them?—Yes; I will give you a list of them. Of course, the place Mr. Tatton referred to, Oldham, has a very large filtering area in operation. Perhaps you will allow me to supply you with a list?

577. (*Professor Foster.*) I do not know whether I should ask you now or when you come on again. Your examination of the effluent is chemical only?—Chemical only. If you would allow me before you pass from that question I should like to refer to the difficulty we shall have in dealing with it in the way in which you desire it to be presented. There are many works which have carried out artificial filtration which are classified as not involving biological conditions, and in many of those works Polarite filters have been put down which were totally inadequate to deal with the volume of sewage to be dealt with. Consequently these artificial filters have failed, and the results from those—I do not know that they would carry much value. For instance, the Corporation of Hyde, given a certain quantity of effluent, were able to obtain a very good effluent, but when they increased the volume they obtained a bad effluent.

578. What was their system?—That was the Polarite system; they precipitated the sewage first in tanks and then the effluent went through Polarite filters.

579. What we wanted to know was where each of these particular systems or processes was being carried on. Under the phrase of "filtration" there is a variety of methods, and if we could have what may be considered typical instances of these several methods, including what you speak of as the biological one, it would be very useful. But to return to my questions. There is no bacteriological examination of the effluent ever made?—No.

580. I mean, it is a matter of indifference whether the effluent contains micro-organisms or not?—Well, as regards the Mersey and Irwell works, certainly that is so; that has not been taken into consideration.

581. Never has at all?—Never has at all.

582. There is no bacteriological examination?—There is no bacteriological examination at all.

583. I do not know whether I should ask you this now or when you come up again. Taking your biological method, is that result at all modified by the previous treatment of the sewage?—Oh, yes, it is.

584. Largely?—Largely.

585. So that, I mean, it might be exceptionally useful for one kind of sewage, but would not be nearly so useful for sewage treated in a different way?—That is so.

586. I mean, for instance, does the entrance of certain refuse make a difference?—Certainly. Take the sewage of Manchester. The sewage of Manchester presents far greater difficulties than the sewage of Exeter. Each sewage must be taken on its own merits.

587. (*Professor Ramsay.*) I think it was said that the amount of solid matter was the only test at present applied?—Yes.

588. In paper works would it not be possible to settle the solid and to deliver the soluble into the river without your objecting?—Not with the qualification I made—that you take the volatile solids in solution into consideration. For instance, there is esparto-liquor; if they allowed this esparto-liquor to escape they would get a very high yield of soluble solids which would settle out on standing.

589. Then merely suspended matter, roughly filtered, could be run into the river, could it not?—Yes, that is so.

590. So that it is a very imperfect test?—Yes. It is only a rough guide to the Committee in bringing out, first all the solid matter; we should then have to deal with the soluble matter.

591. You are putting on the squeeze slowly, in point of fact?—Yes.

592. And the test which is applied as regards the oxidisability of the organic matter is permanganate of potash alone, no other plan such as absorption of free oxygen?—No; we have not adopted regularly the dissolved oxygen test.

593. Has it turned out on the whole in your experience a fair test? Because under ordinary circumstances no sewage is treated with permanganate of potash, but does absorption of oxygen from permanganate and absorption of free oxygen give the same results in your experience?—I find permanganate of potash to be the most reliable test. If you have these effluents presented to you, and you do not know their history at all, if you do the permanganate test by taking the three minutes test together with the four hours test, you are more likely to arrive at the correct conclusion as to their quality than by any other test.

594. What grounds have you for saying that that conclusion is correct? Have you made tests as regards the absorption of free oxygen to see if that is so?—Yes, I have done that. I corroborated it in a great variety of ways. If you take a sewage effluent and you wish to know if it is suitable to pass into a river, you take your three minutes observation and your four hours. Another sample you put in the incubator and keep it there for five days, and you get a certain result. If you continue and apply further tests—suppose you put into that effluent five grains of free lime, put it in the incubator, take the sample out every day, and take the rate at which the free lime disappears, which is a measure of the carbonic acid produced, that gives you a curve which is very valuable to know. We have measured the vitality, if you might call it so, the vitality of the organic life in the effluent by chemical means, that is, by taking the amount of carbonic acid produced, the amount of what we call "stink" produced is measured by the three minutes test, but we have not applied any true biological investigation to the matter. When I say "we," I mean for the Mersey and Irwell Joint Committee, but you are aware of the experiments which Sir Henry Roscoe has made on the isolation of specific organisms from sewage and their character, their power to absorb oxygen, and that sort of thing.

595. How can you know surely that an organism developed in the liquor would become more oxidisable than the original substance?—I do not follow that.

596. I presume you to say that the amount of permanganate taken after standing is greater in the case of a bad sewage than it would be if the sewage were not a very noxious one?—Yes.

597. I cannot see what grounds you have to go upon in supposing that the substance you produce by the degradation of the original organic matter in the sewage is more oxidisable than it was originally?—It is only the value of saying that you must distinguish organic matter liable to putrify from organic matter not liable to putrify. It is not so much the quantity; we do not want to know the quantity, but the quality, and I do not know of any biological process by which you can gain the number of organisms which produce a stink and those which do not produce a stink, but I do know how to measure the vitality by chemical means of those which do produce a stink under conditions favourable to putrefaction. As Angus Smith established the fact that the vitality of the soil depended upon the amount of sugar consumed and the hydrogen gas evolved became the measure of that vitality, in the same way I measure the amount of stink produced by the permanganate consumed.

598. It may be all right, but I do not see the argument.

(*Professor Foster.*) Is it this, that when the fluid first comes out something in it has exhausted a certain quantity of the matter which gives you your action on the permanganate, has brought it into such a condition that it does not take up oxygen from the permanganate?—That is so.

599. But on the presumption—which you do not know, because apparently you do not examine—but on the presumption that there are micro-organisms in that material those micro-organisms produce upon that material such a change that part of it is converted into material which is rapidly oxidised?—That is so.

600. That is your hypothesis?—Yes.

601. But I suppose you acknowledge it is an hypothesis?—I simply go upon the work I did with Angus Smith. If you take a sample of sand and invert it in a tube over mercury with grape sugar you find no hydrogen evolved; if you take soil you do; if you take manure you find a very large volume evolved. Angus Smith said he measured the vitality or activity of the organisms by chemical means in this way, and I do not know of any biological process. If we had a biological process whereby we could say that so many organisms were liable to produce a secondary decomposition in the sample that would be of very great value to us if that could be ascertained within a certain number of hours.

602. (*Professor Ramsay.*) But since you never examine whether there are any micro-organisms at all how do you know that the matter has anything to do with micro-organisms?—I only know that the changes must get brought about by these micro-organisms.

602*. That is the assumption, but how do you know as a real matter of fact, since you do not examine for the presence of micro-organisms, that there are micro-organisms in these effluents to carry out the changes which you assume they do carry out?—We know that if you sterilize the effluent it will not produce any odour, therefore, we know it is organic life.

603. (*Major-General Carey.*) Have experiments been

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made to try whether by using antiseptics the amount of permanganate required is lessened?—That is so, and we have had to guard against the incubator test for this reason, that there is a tendency to render the effluent slightly acid, and if you have any foreign substance such as the present it will throw away the value of your incubator test. For instance, if it is on the acid side you destroy all your organisms and you get no change. If you have carbolic acid or chloroform present in the same the effluent is sterile. So that I say we know that it is life that produces all these reactions.

604. (*Professor Ramsay.*) Quite so?—That is why we do not rely upon the incubator test as the sole test, nor the permanganate test; we like to have as many tests as possible.

605. Albuminoid ammonia as well?—Yes. If you take a sample, analyse it, apply the albuminoid ammonia test, you get a certain amount, 0·25 grain yielded; you put it in the incubator, and at the end of five days it is 0·15. What is the result?

606. What has become of the nitrogenous matter?—In the majority of cases it precipitates out as insoluble matter; all these elements decompose with a sedimentation. That sedimentation contains the organic matter. You see that fully illustrated in the Ship Canal at Manchester. Where the putrefaction takes place the albuminoid matter is decomposed. Everyone says that that water is bad; it stinks, they fly from it, and yet if you relied upon your albuminoid ammonia test you would have to classify it as a good effluent. Therefore you must have all these strings to your bow in estimating the value of an effluent, but generally speaking if the effluent has been treated on biological lines the incubator test is the most valuable test you have. That is based upon some 10,000 experiments which we have made within the last two or three years.

607. You take that test as the test of the purification of sewage?—Yes.

608. From a biological point of view; when I visited Dr. Angus Smith he was then beginning to utilise gelatine for the cultivation of micro-organisms?—Yes, and I have tried, and within the last year, to utilise the biological process, and I must admit that I did not get the value from it that I got from what Dr. Angus Smith termed "measuring the vitality of living forms by chemical means." I have his two reports to the Local Government Board dealing with that question, and in my opinion it is of far greater, certainly of more, practical value to measure them by chemical means than by biological, because, if you take those effluents and estimate the number of organisms, it is of very little use to you, except to discover a source of pollution in the river. For instance, if you take the number of organisms in the River Dee, as Dr. Frankland did, you can get at the sources of pollution, but in the same way by the oxygen consumed you get an identical result.

609. Another question. It has been said, I think, by Mr. Tatton and by yourself, that a clay soil is not a very efficient purifier. I presume you would modify that statement, inasmuch as it is not always necessary for the effluent to sink through the soil; if it ran over a sufficient amount of soil it would be purified?—That is so. In the Commission's Report of 1868, Warwick is referred to. There they had great trouble when they first started at Warwick with land filtration. The land opened; it opened to the extent of three feet deep, where the water all ran direct into the drains, and then they found it was better to run it over the surface, and what did sink was brought up for a second filtration. That has also been carried out at Leicester, where they now claim to have got very efficient results from clay. But when you come to clay—clay land ought to be entirely avoided, because on clay land the volume of effluent which you can deal with is so small that it has practically no value as a filtering medium. When you come to consider the works pointed out in the report of 1868, and you look at the volume of effluent which passed over the land, you will find it very little. At Edinburgh, where sewage irrigation is followed, it is not worked for the purposes of purification, but for the purposes of utilisation. There they only filtered two gallons per square yard per day. Perth, that is only ·4 of a gallon per square yard per day. And Warwick was 1¼ gallons with clay land, and was a failure. Take good soil; for instance, at Croydon they are able to filter four gallons per square yard, while clay soil was only ·8. If you are going to take large towns, and it is those we want to deal with, the area of land required is outrageous; it is not practicable to apply the sewage of a large town to irrigation over land.

610. (*Major-General Carey.*) I suppose it may be combined with precipitation, may it not?—Quite so. Take, for instance, the population of Manchester. They have already adopted precipitation; they have tank accommodation for the whole of the sewage; they precipitate the whole of it, they get an effluent which is not fit to be discharged into any river; they must carry out some form of filtration. If it is land filtration, from the experiments we have made at Manchester, they cannot filter more than 60,000 gallons; it would not be advisable to attempt more than 60,000 per acre, and consequently they would want nearly 1,000 acres of land. On the other hand, if they have artificial filtration on biological lines, worked on the intermittent system, they can do then with a very small area. The effluent from that artificial filtration area would be to all intents and purposes satisfactory to be discharged into the Ship Canal.

611. That is a matter of experiment, of course, up to the present?—Yes, based upon the two filter beds of 25 square yards each. The effluent resulting from this would, I think, satisfy the requirements of the Mersey and Irwell Joint Committee. On the other hand, where an effluent is to be discharged into any river which is at all likely to, or does form the water supply of a town, I think it is imperative that nothing but land filtration should be resorted to.

612. Taking the samples for analysis, do you allow the first rush of the filter to flow off, or do you take the first flow of the filter?—In the Manchester experiments we took it over the whole period.

613. From the very first?—From the very first to the very end, and we have also worked that problem out to see whether the first portion differed from the middle portion, and whether the middle portion differed from the last portion, and we find that if the filter beds are not constructed properly—for instance, many filter beds are constructed whereby there is a volume of dead water left which is not purified. That is bad. But if they are properly constructed—you will find the filter beds at Manchester are satisfactory from the commencement, and that is owing to the construction of the filter beds. The filters at Manchester are somewhat different from those advocated by Mr. Dibdin. The filters at Manchester are graded filters, and, I think, in any form of biological filter gradation is required, so that by having the fine material at the top you are able to spread the effluent water over the area better, and get downward filtration. If you take a biological filter and fill it from the bottom you do not get efficient filtration. It is not a question of these animals, as it has been popularly explained, perching on this material and devouring it; it is a question of percolation. You must have slow percolation through the filtering material, and you must have the material at the top of the filter so fine that it will evenly distribute the effluent. If not, you get into difficulties the same as with clay soil, and, therefore, in recommending artificial filtration I only recommend it on the understanding that the filter beds are properly constructed.

614. And that only a certain proportion of sewage goes on to them?—And only a limited amount of sewage goes on to them, which must be fixed by the quality of each sewage that you take; it must not be regulated by population.

615. 800,000 gallons, is not that rather more than Dibdin's filters?—Dibdin's was 1,000,000 gallons, or 200 gallons to the square yard per day. Of course when you come to study this question you will have to go very carefully into what each works has got. At Sutton they have reduced it to 170. If you take the experience of the Barking filter for three years it comes to 90 gallons a square yard, taking in the periods of rest

616. (*Chairman.*) Should you mind letting us have a list of the places in which your experiments are being carried on?—I will, with pleasure.

617. And with a very brief description of the process?—Yes, and with the results. Would you allow me to extend that also to manufacturers' works. Do you think that that is essential that you should have samples of manufacturers who have carried out works?

618. We shall be very glad to have anything you can send us?—I can give an instance of a manufacturer who has spent £1,200, and compare the efficiency of his process with one who has spent £9,000. But, as I explained, we rather wanted that left over for a little while, and to confine our evidence to-day to the Mersey and Irwell Board.

619. (*Major-General Carey.*) What rules and regulations have been issued by the Mersey and Irwell Board about pollution?—I think there is some regulation with

regard to Manchester. I think Mr. Tatton had better answer that question. (*Mr. Tatton.*) The only regulations are in regard to the Manchester Ship Canal; they made arrangements so that the sewage should be diluted.

620. I was under the impression that the Joint Committee had laid down some definite proportion of dilution of sewage with stream water before it came into operation?—They have not definitely. No, we tried to get seven or eight to one, because it was fixed by the Ship Canal.

621. There is no rule or regulation?—There is none on that.

622. (*Colonel Harding.*) Upon these analyses, the results of which are tabulated before us—the analyses of the filtered effluents. Do you take the effluent after it has stood a little time?—You cannot analyse it immediately; after you take it it deposits a certain amount of solid matter. Are the analyses the analyses of the filtered effluent?—(*Mr. Scudder.*) Oh no; they are all shaken up—all in. *Mr. F. Scudder, F.C.S., F.I.C.* 12 July 1898.

623. (*Chairman.*) In what state are they?—They are analysed in the state in which they are received.

THIRD DAY.

Wednesday, 13th July, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*)

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

Mr. FRANK SCUDDER, F.C.S., F.I.C., recalled; and further Examined.

624. (*Sir Richard Thorne.*) Mr. Scudder, yesterday you used two terms, namely, "good effluent" and "fair effluent." May I assume that the good effluent is where the oxygen absorbed does not exceed 0·6 of a grain of per gallon?—The good effluent. *Mr. F. Scudder, F.C.S., F.I.C.* 13 July 1898.

625. The good effluent?—The good effluent is where the oxygen absorbed does not exceed 0·6 of a grain of oxygen absorbed, but one grain includes good and fair.

626. Pardon me, we will stick to the good, if you please, first?—Yes.

627. Then the limit of what Mr. Tatton described as good which was a limit of impurity estimated by one grain per gallon of oxygen being absorbed in four hours is not your good effluent?—No; it includes the fair effluent.

628. I want the definition of the two, the chemical definition of the two words "good" and "fair" effluent?—Yes, I will call "a good effluent" an effluent that does not absorb more than 0·6 of a grain of oxygen per gallon in a four hours' test, "a fair effluent" one that does not consume more than one grain of oxygen per gallon.

629. Then as long as it is clear it is evident that you use a different standard to that which he uses as regards what is a satisfactory effluent, he having only the one standard?—Yes; having only the one standard he only works upon that one.

630. Now, may I ask you with regard to some of those tables which you have put in. Here is "Bleachworks Table B," in your Return. You there appear to contrast the solids in suspension and in solution of a crude effluent before treatment, and a purified effluent after treatment, do you not?—Yes, sir.

631. Well, now, in the table relating to bleachworks you give twenty-three different effluents?—Yes.

632. But, as a matter of fact, you can only compare four. What is the value of the remaining nineteen to us?—That is so. I only give in this table four examples of the effluent which was derived from the crude effluent treated, but the value was to be taken on the whole to show that, generally speaking, the effluents may be obtained practically free from suspended solids.

633. It is nineteen out of twenty-three?—In the ten cases of purified effluents. I had not in these ten cases the original material to compare.

634. Then they really are useless for the purposes of comparison?—Oh, for the purposes of comparison they are, but they are useful this way, as showing what percentage of solid matter is removed.

635. (*Mr. Killick.*) The presumption is, I suppose, that those which you did not investigate were more or less similar to those which you did investigate?—That is so, sir.

636. (*Sir Richard Thorne.*) I see. Then as regards the two tables further on, headed D, the defect, if I may so call it for the moment, is even more striking because you have three cases in which you compare the effluent before treatment and after treatment?—That is so.

637. Would the explanation be the same?—The explanation is the same there.

638. But as regards the solids in solution, I notice that after treatment some of these exceed the amounts contained in the crude effluent?—Solids in solution.

639. Yes; take, for example, the item 14; you have 123·5 grains per gallon solids in solution?—Yes.

640. That is after treatment, is it not?—That is after treatment, yes.

641. Well, in some of the others before treatment at all you have only 90 and 45 and 84 and 86 grains?—Yes, that is so.

642. So what is the real value of this tabulation?—You cannot compare the two ways: that is my real point?—Well, the real value is only to show that as regards the solids in suspension they are considerably reduced.

643. Oh! the solids in suspension?—Now, if you take the solids in suspension in the list 7 the highest result is 13·5, while the lowest result of the crude is 13·8.

644. You limit your comparison to solids in suspension?—Yes; in these four tables we have got out, they show the varying quality of the effluent derived from these various manufacturers. For instance, the crude effluent contains only 13·8 grains in suspension; on another occasion they go as high as 145.

645. Yesterday I understood you to say that the sewage of Manchester presented much greater difficulties than that of Exeter as regards treatment under the so-called septic system?—Yes; that is so.

646. Would you kindly tell me why that is so?—Well, the sewage which is treated at Exeter is purely domestic, is free from any manufacturing refuse; on the other hand, the Manchester sewage contains a variety of trade effluents, chemicals, etc., so that when this sewage is submitted to a septic tank treatment putrefactive decomposition takes place with the evolution of sulphuretted hydrogen and other offensive gases, whereas the sewage which is treated at Exeter decomposes without the evolution of sulphuretted hydrogen or other offensive gases, but hydrogen and marsh gas are given off. Manchester sewage decomposes with the evolution of a smell. Exeter sewage decomposes without the evolution of a smell. These are the distinguishing features.

647. I anticipated a good deal of your answer, but what I now want to ask you is this, does that mean that when you have trade and chemical refuse added to the sewage you will probably get the micro-organisms on which the septic process depends destroyed?—I think so, sir.

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648. And so these organisms will be unable to carry out the work which is claimed in the septic system?—Yes; I think that is so.

649. Thank you. I did not quite understand yesterday what your relation to the Mersey and Irwell Joint Committee is, because at one time you offered personally to hand over to us some Manchester works; at another time you used the word "we" as regards works that were being carried out, and then again, as I understand, you claimed to represent the Mersey and Irwell Joint Committee?—Yes.

650. What is your precise relation to the Committee?—Sir Henry Roscoe is the scientific adviser to the Committee; he is not an official of the Committee, but Consulting Chemist, and I am Sir Henry Roscoe's assistant, acting under him, and Sir Henry Roscoe, in his capacity as a chemist, advises sanitary authorities and manufacturers.

651. Then you are not an official who gives your whole time to the Committee?—Oh no.

652. Have you any relations with Manchester now?—Not at the present moment.

653. (*Chairman.*) Taking up what Sir Richard Thorne was saying about the difference between Manchester and Exeter, were you, or any people connected with you, present at the inquiry at Exeter last autumn?—I was not, my lord, but I have been at Exeter and investigated the process there.

654. You have?—Yes.

655. When you say that a process which might succeed at Exeter with any domestic sewage might not succeed at Manchester, where the circumstances are different, are you speaking from actual experience or expressing an opinion?—I only know that from laboratory experiments; I do not know that from practical working.

656. But you think from your laboratory experiments that the probability is that it would fail?—I think so because I have tried in the laboratory to get Manchester sewage to evolve these gaseous products of hydrogen and marsh gas, and have failed to do so. On the other hand, if you take purely domestic sewage, pure excremental matter, you can get hydrogen and marsh gas evolved without the production of sulphuretted hydrogen.

657. Then I wanted to ask you one more question, which is, perhaps, a fad of my own. I have always got the greatest detestation of seeing milk cows feeding in a marsh or anywhere which is part of a sewage farm, but I presume milk cows do feed everywhere all over a sewage farm?—I think so. Take Birmingham, for instance, they have had to have cows there to eat up the grass.

658. And you have never heard of any harm coming, or any mischief coming from that?—Oh, no; not at all.

659. Well, now, a friend of mine told me the other day that a case of gastritis appeared among a herd of cattle. This was in Buckinghamshire, I think, and that it was supposed to have come from the cattle having drunk from a pond which was polluted by sewage. Now, you would have no experience of any parallel case to that or anything like it?—No; I have often been involved in cases where they have said cattle having drunk out of river water have suffered from poisoning from manufacturing waste, waste from a calico print works. I have known a case where a farmer came into Court and declared that his cattle had suffered from drinking the river water. On the other hand, I think if you ask people who keep cattle and who study animal life, you will find that cows are very careful; they will not drink anything that is disagreeable to them; and I do not think that man proved his case.

660. That is trusting a great deal to the sense of the cow?—In the same way you go into farmyard, a poorly-kept farmyard, what do you find? The pond in the yard where the cattle go to drink just fœtid with sewage polluted matter.

661. (*Sir Richard Thorne.*) Quite so; is it not that which gives force to his Lordship's question? They drink the filthiest stuff whether from the point of view of taste, smell, or sight?—Exactly. That would be my reply to that, for you find cattle in country places in these dirty ponds going and enjoying that water, drinking it, and suffering no hardship.

662. (*Chairman.*) But then that shows that the cattle have not got the sense to avoid the unwholesome stuff?—But they do avoid it; if there is any manufacturing refuse in the stream they do object to it. If you put extract of logwood down a stream a cow comes and looks at it, but does not drink.

663. But you do not know any case where it is proved that cattle have suffered from such a matter?—No.

664. Then do you believe that the land goes on for ever filtering sewage as efficiently as it does at the beginning?—If the land has been properly attended to, properly worked, legitimately worked, it will go on indefinitely purifying it; and in proof of that I refer you to Croydon where, in 1876, I went with the late Dr. Angus Smith, and analysed the effluent. If you go to that very same area of land and analyse it, it is equally good, therefore there is an instance of land being in use thirty years working efficiently.

665. And you do not think the land deteriorates in any way?—No.

666. Does not get foul?—No.

667. (*Mr. Killick.*) Might I ask what you mean by properly worked?—Well, principally by intermittency. If you take a piece of land and keep it continually under sewage, then it will become foul and bad, it will take a long long time to recover itself, but if you work it intermittently, then I say it is everlasting.

668. That is the essential thing?—That is the essential thing, intermittency.

669. By working you do not mean any preparation?—It must not be inundated.

670. You do not mean any artificial treatment of the land, you simply mean the intermittency of the use?—Yes.

671. (*Professor Ramsay.*) Might I ask if you refer to pure sewage or manufacturing refuse?—I refer to the sewage of a town.

672. Of such a town as Manchester for instance, with a great many trade effluents in it?—That would do equally well if they only put the volume it was capable of dealing with, if they ascertained that one acre of land could deal efficiently with 60,000 gallons, and that was based on twelve months' experience, then, I say, at the end of thirteen years it would still go on dealing with 60,000 gallons, but if they commence one acre of land with, say, 200,000 gallons, it will purify for a few months, and then stop.

673. But the point of my question was, do you regard this as referring to trade effluents equally well with sewage?—Quite so. I think if you take the report of the Royal Commission of 1868, they established the fact that pure manufacturing waste, free from sewage matter, was most efficiently treated on land.

674. (*Chairman.*) Just one more question about the clay land. Mr. Tatton told us yesterday that he was speaking chiefly about grass land. Well, of course, the surface of grass land is not broken up, it remains undisturbed from year to year, but do you consider clay land equally unsuitable for filtration purposes when it is arable, and when it is ploughed up every year?—Yes. I consider clay land is unsuitable under any conditions for this reason that you cannot get what I call a legitimate volume of effluent through it; you cannot filter a sufficiently large volume to make it of practical use.

675. (*Major-General Carey.*) Does not that mean that you would require a much larger area of clay land than good land?—Quite so. When you come to estimate what area of clay land will be necessary it is ridiculous to ask them to acquire that area of land; they cannot get that area of land.

676. (*Chairman.*) You mean that the effluent does not penetrate the clay; that it silts back?—That it does not penetrate; it does not get through.

677. You mean it silts back?—It would choke the filter; you could not get any volume to give it any practical value, and that is the reason why in many places where they have got clay land they have gone to the expense of burning it, and making it more porous; the idea of burning it is to make it more porous, and then it becomes really an artificial filter.

678. And you do not consider that the fact of its being treated for arable purposes—broken up, ploughed up, makes it an effective filter?—No, I do not, my Lord.

679. (*Major-General Carey.*) There is one point that I should like to ask Mr. Scudder. We have had comparative results of precipitation and artificial filtration as compared with precipitation and filtration through land, and they are said to be nearly equal, as far as I understand—precipitation and artificial filtration against precipitation and land filtration, and the results were given to us, as I think they are, nearly equal in a certain number of cases. Now, of course, it is a fact that good management enters very largely into the question of

results—good management and supervision?—Oh, quite so; I quite agree with that that good management is very important.

680. Whatever process is adopted?—Yes.

681. And in the case of artificial filtration would it not be more difficult to obtain satisfactory results, we will say from an indifferently managed system of filters than from a sewage farm with precipitation and land filtration equally badly managed?—No, I would rather rely upon a man who was given to irregular working to manage an artificial filtering area than I would a land area. My experience has been that you find very few men who really understand how to apply liquid sewage to land. On the other hand, you can very easily train, and you can very readily obtain men who act almost like machines. We have mechanism that can do away with the men employed on the sewage filters, and these filters may be worked automatically, and if you have filter beds worked automatically, you are more sure of your results.

682. Take Oldham or Chorley, which have works and filters on a large scale?—They are just about now to put in this automatic arrangement for working filters. When that is in they will get far more concordant results than you can get relying upon men.

683. My question referred rather to the small places; places where indifferent management is perhaps the rule, and I should like to have an opinion of what would be the result of a badly managed filter; for instance, when it became clogged there would be no satisfactory result at all?—I may illustrate that by referring to a small place like Swinton where they have had land filtration for a long time. The manager there certainly does not understand the principles of land filtration, but there was the land, and he had to use it to the best of his ability. He was constantly producing bad effluents, and the Sanitary Authority was brought up before the Mersey and Irwell Joint Committee. They then adopted two cinder filters—and they were so much easier for this man to work, that since their adoption, and getting into good working order, they have had no complaints. They require less attention to work than the land.

684. They have taken great pains, I presume, at Swinton to filter this sewage efficiently. Take a small place in a rural district, the moment a scheme is approved or a loan sanctioned, they begin to hope that the works will take care of themselves?—Yes. Well, of course, everything if you neglect it will go wrong, and if you have an artificial filter bed and it is not properly attended to it will go wrong equally well with land.

685. That is my point?—I do not think it will go wrong because it is more porous. It cannot get through land; it stops and becomes bad.

686. (*Chairman.*) You asked me, I think, to put these questions to you, and I think Professor Ramsay has a question or two to ask on the same subject. What is your opinion as regards the Royal Commissioners' standards of 1868, and are you in favour of fixing definite standards?—Well, with regard to the standards of the Royal Commissioners of 1868 some are too severe and others are too lax. It is rather a mistake to refer to them as standards of purity; they are really limits of maximum impurity allowed for effluents. If I might be allowed I should like to go through those limits of impurity which have been fixed. They are described in the fourth report on page 164. With regard to the first standard: "Any liquid containing in suspension more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter, in 100,000 parts by weight of the liquid." That was a standard which was to be enforced in the case of sewage works, in the case of calico printing works, dye works, silk works, paper works, skinners and tanners. With regard to sewage it is too severe a standard, inasmuch as many of the best effluents that we get from land contain in suspension more than the amount allowed here "three parts by weight of dry mineral matter." On the other hand it is too severe a test for the effluent from paper works and the effluent from calico printing works. I have been engaged in cases where considerable contention has been involved with regard to the interpretation of what is "dry organic matter." Is the "dry organic matter" to be taken at 100 degrees centigrade or at 110. On the other hand, how is that "dry organic matter" to be determined. The only method which is available to the chemist is to determine the organic matter by combustion. Well, now, it all depends on what solids you have got in your water. It depends whether or not you have got water of combination in the solids which is not organic matter, but which is volatile. For instance, if you take an effluent from a well purified sewage farm containing a high amount of nitrates when it has been evaporated to dryness and ignited the nitrates are lost. That goes under the heading "organic matter," which would not be right, therefore a standard like that is, I think, to be avoided. It is commonly brought into trials. One chemist is pitted against another, and the chemist who declares the organic matter is more than "one part of dry organic matter" is contradicted by the other one who proves that it was not dry organic matter that it was the nitric acid that was evolved, or he might say it was inorganic nitrogen, which is not organic matter at all. Therefore, unless it is definitely stated at what temperature you have to take the matter these standards become of very little use. Then with regard to the standard "B": "Any liquid containing in solution more than two parts by weight of organic carbon, or 0·3 part by weight of organic nitrogen in 100,000 by weight." Now, that is not a sufficiently severe standard for sewage works.

687. (*Major-General Carey.*) But that is the sewage effluent standard, is it not?—That is meant for sewage.

688. It is the only clause that applies to sewage?—Yes; that means that you could have ·21 or organic nitrogen per gallon escaping in the effluent. That is not sufficiently severe. On the other hand, it is too severe for the effluent from a paper works, or for the effluent from calico printing works to which it also applies. The third standard: "Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel," that is also too severe a test. No calico printer can meet that requirement, and it is not applicable to calico printing, dyeing, and colour works. What is a distinct colour to one person would not be held to be so to another. We must also bear in mind the enormous tinctorial power of the aniline colours represented by an infinitesimal weight of colouring matter. Now that the aniline colours, the coal tar products, have been so extensively used among calico printing and dyeing works such a standard as that is not applicable. Then we come to standard "D": "Any liquid which contains, in solution, in 100,000 parts by weight more than two parts by weight any metal except calcium, magnesium, potassium, and sodium." That standard I understand was put in in order to protect the mining industry, but it does not protect the manufacturer. It does not, as any standard framed ought to do, have for its object the making of river water usable for the manufacturer. Now, supposing a manufacturer has to purify his effluent he would be allowed to pass away in that purified effluent if he used a precipitation process 6¾ grains of copperas per gallon. We will assume that this manufacturer is in a certain position of the stream, there is another manufacturer down below who wants to draw water for the purpose of carrying on his trade as a dyer. If this man is allowed to throw into the river above him an effluent containing 1·4 grains of iron per gallon, which is the maximum allowed under this clause, to the man below that water would be useless for any purposes of dyeing. Again, supposing that they were to resort to alumina as a precipitant, then the manufacturer who used what is usually used for precipitation purposes, alumina ferric cake, would be allowed to send in 17·2 grains of alumina ferric cake per gallon of his effluent. Now, the effect of that large amount of metals other than those mentioned there would prohibit this manufacturer from using river water. During the last two or three years I have had several cases where manufacturers have been in dispute with regard to pollution of the river, and this very question of the amount of metal other than those specified as allowable has been argued, and that clause is no protection to the manufacturer. Therefore I think it is valueless. The manufacturer has, on the other hand, turned round and said, "Well, what did the Commissioners suggest in 1868?" They suggested that they should be allowed to pass an effluent containing not more than thi· 1·4 grains of a metal. One of the duties, I think, that the Mersey and Irwell Joint Committee have to attend to, and that is, to see that the manufacturer in attempting to purify his liquid does not pass into the river any material that would be hurtful to the man below. I need hardly point out that iron escaping into a river is most injurious to a man who is carrying on the business of a calico printer or a dyer. Alumina ferric cake is equally injurious. It acts as a mordant, and therefore those limits are valueless Standard E is one only referring to arsenic, and I see no objection to that. Standard F is a good one. I approve of Standard F.

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689. (*Sir Richard Thorne.*) Would you name Standard F?—Standard F: "Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one part by weight of free chlorine." Now, that is a very good standard. It protects the river from any injurious effects produced by the discharge of bleaching powder, say, from paper works. Now, paper manufacturers, as a rule, take great care not to allow any free chlorine to escape in their effluents; it is a loss to them if any chlorine escapes. That is so much loss to the works, consequently we find very few paper works which are not able to come up to that standard. And that is really a good standard, applicable to paper works, for which it was framed. Standard G: "Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen, or of a soluble sulphuret"; that is a good standard also to insist upon. Standard H: "Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water." But I will take Standard H, if I may, in conjunction with Standard I, the next standard, because these two were framed for a special purpose. "I" is: "Any liquid possessing an alkalinity greater than that which is produced by adding one part by weight of dry caustic soda to 1,000 parts by weight of distilled water." Now, those two standards were framed for the protection of fish. They do not, however, protect the manufacturer; they do not assist the manufacturer in getting water suitable for manufacturing purposes. On the other hand they are a great drawback to the manufacturer, inasmuch as the escape of water containing $\frac{1}{10}$ per cent. of hydrochloric acid is really excessive, and I know of no manufacturing process where such a large amount escapes. And the other standard "I" is far too lax. The same applies with regard to the amount of alkali allowed. Any paper-maker would be allowed to let the whole of his alkaline liquids escape and come well within that limit. Moreover, it was specially framed, as I pointed out, for the protection of fish, and if you refer to the Commissioners' report, the experiments made by the late Dr. Penny, he found that one part in 50,000 will kill fish instantly, and here you have a standard of one in a thousand, so that it is not an efficient protection to fish. Those two standards, I think, therefore, are valueless. The last standard, K: "Any liquid exhibiting a film of petroleum or hydro-carbon oil upon its surface, or containing, in suspension, in 100,000 parts, more than ·05 part of such oil." Well, that is quite fair as regards the amount of oil that is permissible into a stream, but it does not prevent the gas-maker or the oil refiner from discharging acids into the streams, and the bye-products from wood works containing acid and acetates. It was framed for the purpose of protecting the manufacturers of pyroligneous acid, oil refiners, and the gas works, but it does not touch them at all with their polluting liquids, it only touches them so far as that volume of oil is concerned, and, therefore, that standard is useless. That is what I have to say with regard to the standards. Then with regard to the second portion of the question, whether I think standards are advisable, I think they are not advisable. I have given a considerable amount of attention, and I have always endeavoured to see if it was possible to get at a workable standard. That I have not been able to do, and I think that each case ought to be tested on its merits. To lay down absolute standards of purity for every river would be a mistake, irrespective of the locality and circumstances of the case. I think that the best practicable and available means ought to be insisted upon for the treatment of foul liquids escaping from any factory. If the best practicable and available means were adopted, the manufacturer is protected from any vexatious or harassing litigation put in motion by any conservancy board, inasmuch as you have to show that he is not using the best practicable and available means. If you had a definite standard the manufacturer does not know the limit that he may be driven to. It has often been suggested that it is desirable to have standards in the same way that for the pollution of air from alkali works you have the Alkali Acts, where standards have been in force, but with the Alkali Acts, although rigid standards have been enforced, the manufacturer is supplied with an unlimited quantity of the pure article, namely, air to dilute his escaping gases. The application of similar unvarying standards to the case of water, which is supplied neither in quantity nor in quality to any manufacturer alike, is essentially different. You see, although they fix a standard under the Alkali Acts for air pollution, they take the number of grains in the cubic foot escaping. In the same way if you fix a standard for the polluting liquid, you must also fix the volume of it. A man may have a very small volume of very noxious polluting matter, but if he has a standard given to him he can dilute it down and escape, so that is one of the reasons why I think that this more elastic standard of using the best practicable and available means is better. I think that answers the point.

690. (*Professor Ramsay.*) Might I ask you about the question of analyses and refer you back to your criticism "A" upon the report of 1868 of the Rivers Commission, page 22 of the first document, I think?—Sir Henry Roscoe's report, table 9.

691. You say good effluents are unable to comply with this standard forbidding more than three parts by weight of dry mineral matter or one part by weight of dry organic matter in 100,000 parts by weight of the liquid. I understood you to say that questions of analyses crop up here which make it difficult to say whether there are really the supposed amounts of organic matter in the liquid?—Yes.

692. But I suppose you would agree that it is not of so much importance whether the organic matter is present in the liquid as such as to what may become of the organic matter later on. For example, there are a great many kinds of organic matter which may be present in a stream without doing any harm to it?—I quite agree, and I would like to put that as a primary reason that it is not so much the quantity of organic matter as the quality.

693. Do you not think it would be advisable to apply a test for the quality?—Yes. The difficulty, I think, is in framing a test that could legitimately be used. If you frame, for instance, a permanganate test which would measure the putrescibility of an effluent which we have attempted to do in a certain direction on our watershed, we found immediately that people resort to means whereby that test is frustrated.

694. By antiseptics?—By antiseptic treatment. For instance, I know of a case where the effluent put under the incubator test showed no tendency to putrefaction; it was simply pickled by carbolic acid.

695. But would not its condition from carbolic acid have brought it under one of the other headings?—The subsequent dilution condemned it, but with the incubator test it did not get any worse; it was pickled for the time being. We have to attenuate the action of the carbolic acid by dilution, and by diluting it we then get the secondary decomposition to go on.

696. Then you admit it is possible to test this even when carbolic acid is present?—It is, but it requires refined methods of analyses; for instance, we have to use the lime method for one. If you have free lime present the effluent does not undergo secondary decomposition, but the rate at which the free lime disappears is a measure of the changes which the organic matter in the effluent are undergoing. In the same way, if you take the effluent and estimate the rate at which the dissolved oxygen disappears, that is of great value in conjunction with the permanganate test.

697. Taking these refined methods into consideration, it would be possible to make a standard in this respect?—Yes, and practically as a scientific chemist I have my test. In cases of trial or dispute, where other chemists are involved, I use every test I possibly can. I want all those available in order to arrive at a definite opinion with regard to whether that organic matter is liable to become offensive.

698. Then do you not think that this standard could be generally applied; what is to hinder this standard which you apply occasionally and in cases of dispute from being generally applied?—Nothing, except that it is a standard that only a scientific chemist can use. I should not like a standard like that to go out and be used in the same way that Wanklyn's process for estimating nitrogenous organic matters has been used by chemists.

699. But to apply your analogy with the Alkali Act the hydrochloric test can be applied only by a skilled chemist?—Exactly; oh! if you do it in the same way; if you stipulate at the same time that these tests are to be carried out by skilled chemists then I am with you. I think that can be done.

700. I can quite see the objections you take to various points raised in these paragraphs, "A," "B," "C," and so on; I do not think they need going over in detail; it appears to me that your criticism is just enough?—I may just make one further observation, if I may, with regard to standard "A" that is later from the page that I quoted from—a later period at page 49 you find they say this: "Any liquid which has not been subjected to perfect rest in subsidence ponds of sufficient size for a period of at least six hours."

701. Yes?—Well, I do not think that it would be fair to the manufacturer to insist upon him holding his liquid

up for six hours. Some of the very best effluents are got by holding them up for two hours, so that you cannot even fix the time or conditions like that; each must rest upon its own merits.

702. Then I had better pass your comments on "B," "C," and "D"; they appear to me quite justified, and also "E." which deals with arsenic; you cannot accept that?—I have no objection to that standard. Of course, from the Mersey and Irwell point of view we have not attempted to deal with arsenic; that is only for the protection of life.

703. Then you also accept "F" and "G," which practically amounts to accepting standards?—Yes.

704. "H" and "I" you think not stringent enough?—Not stringent enough.

705. Would there be any objections to making them more stringent. The one refers to alkali and the other to acid; would they interfere at present with manufacture?—Not at all; it would not interfere with manufacture. I know no manufacturing process which turns out effluents anything like these.

706. But in very much less quantity?—I think it would be good if we could guard against the discharge of free acids or the discharge of free alkalis, but it would be very difficult to arrive at what would be a legitimate limit.

707. It can be arrived at?—It can be arrived at—oh, yes.

708. And of course in the case of trades if there were inspectors appointed they should not press too hard on manufacturers at first?—Quite so. Take for instance the bleacher, practically the whole of his alkali escapes, and the way that we have had to deal with the treatment of bleachers' Kier liquors, which is really a strong alkali, is this: the liquors are stored and distributed over the whole of the effluents, thereby reducing the alkalinity; but if he was allowed to discharge this liquid direct into the river it would then be a very polluting liquid, but it would come, and we have had cases where it has been contended that the liquid has come within these requirements. Again we have had a case where alkalinity is involved with a sewage works. They discharge along with the tank effluent free lime. They used an excess of lime; they had five or six grains of free lime escaping in their effluent; as soon as this met with the river water it precipitated carbonate of lime. "But," said the authority, "they come within the limits of the Commissioners standards, we meet "the requirements." It is not a very strong alkali, but it is most injurious that six grains, which form very nearly twelve grains of carbonate of lime, and then at the same time there is carried down a considerable amount of organic matter. We want to stop them going into a Court of Law and arguing that they are protected by standards which were suggested in the Commissioner's Report of 1868. You must bring it down so that the alkalinity must not exceed one or two grains to the gallon to make it effective.

709. Quite so; but you think there would be no great difficulty in getting such a standard kept to in course of time—perhaps not at first, but in course of time?—In course of time I think it would, but not at first.

710. Pyroligneous acid would come under the designation of acid?—Quite so.

711. It would be stopped in that way?—But then from pyroligneous works there is very little crude pyroligneous acid escapes, but crude acetates will pollute a river for a considerable distance, and yet it escapes under this standard.

712. Charcoal?—Charcoal.

713. But do you refer to the escape of powdered charcoal in your criticisms?—Well, powdered charcoal is not protected here.

714. Would it not come under the head of suspended matter?—Yes, I think it says here that this was specially framed for pyroligneous works, which are practically charcoal works.

715. Yes, but it surely would come under the head of suspended matter?—Yes, but this specially refers to "A" and "B" suspended matter, and they have not incorporated this.

716. Then I may take it, I think, on the whole, that in spite of what you say in your next paragraph you are not averse to a standard?—I am not averse to a standard if the standard is to be carried out by scientific chemists.

717. (*Sir Richard Thorne.*) You stated just now that you thought each case ought to rest on its own merits?—Yes.

718. What do you mean by each case?—Each case of pollution.

719. Not each river?—Not each river, no; each case of pollution, each manufacturer, or each authority.

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720. Then who is to be the judge of these merits all over the Kingdom?—Well, you will have to have authorities similar to the Mersey and Irwell Joint Committee all over the Kingdom. For instance, the Mersey and Irwell Joint Committee take the authority of dealing with each manufacturer on his own merits.

721. Then that means that you desire to have each watershed in the Kingdom under a Board which is comparable to the Mersey and Irwell Board?—That is so. I think that would work better, because if you have each county with its own authority, like we have, the members of that authority are well acquainted with the industries carried on, in many cases they are well acquainted with the manufacturers personally and with the authorities; in fact, the authorities are represented on it, and consequently we know what is desirable to get and to get at.

722. Yes, but if they are to be the judges then they cannot be the prosecutors?—I do not see why, as we are at the present time. For instance, take a manufacturer, what is the procedure? The Mersey and Irwell Joint Committee decide that this man is not doing his duty, that he is not using the best practicable and available means. He is invited to attend the Joint Committee and show cause why proceedings should not be taken against him: he is then told distinctly and clearly what it is that we object to and he can cross-examine and discuss the matter with us. If he insists that he cannot do any more and will not do any more we call upon the Local Government Board to hold an inquiry. They hold an independent inquiry, and it is upon their certificate whether we are allowed to go into a Court, or not.

723. Quite so, then it is not the Joint Committee that judges; the Court or the Local Government Board judge on scientific evidence, and the person who is prosecuted can bring any amount of evidence counter to that which the Committee bring?—Quite so; but we form an opinion first: the Joint Committee decide.

724. Then as regards some of your objections to these tests, these standards—I would just take one. You object, for example, to 1¼ grains of iron per gallon as a standard on the ground that if that were admitted in an effluent it would render the water below useless for the purpose of the manufacturer below?—Yes.

725. But surely this must depend upon the body of water with which the iron is mixed?—It does to a great extent, and I point out this that one-tenth of that standard would render water, if it were diluted ten times, useless to a manufacturer who happens to be a calico printer or a dyer, and the cases that I have been connected with scientifically where manufacturers dispute with regard to the water, you often find that the water is impounded from these streams upon which these works are situated. A manufacturer will open his valves to the reservoir at six in the morning, and take water on till twelve. During that period the man below has only available for his purposes the effluent coming from the works, so that a standard is no use unless you can fix such a standard that it cannot possibly under any conditions become hurtful to the manufacturer.

726. Well, that means in the case of a very small stream with a large number of manufacturers upon it, an almost impossible standard does it not?—It does not follow that there may be a large number of manufacturers. Take some of the streams, there may not be more than two manufacturers on that stream, and the one below being a riparian owner has compelled the man above him to remove the whole of the iron, and send him down water which is usable. I think the object we ought to have in view in any standard is that it is to render the water usable for the purposes of manufacturing. Apart from sewage, of course, we treat sewage from a health point of view; if we are going to treat manufacturing waste, we must treat it from the point of view of obtaining water which is usable to the manufacturer, to bring back the streams to their original condition—to the normal condition.

727. To the normal condition?—To the normal condition.

728. (*Professor Ramsay.*) The ideal object, I suppose?—That should be the object, yes.

729. (*Sir Richard Thorne.*) But, after all, any standard, I presume, must depend on the number of manufacturers on the stream, and upon the bulk of water in the stream? You might have a standard, for example, so far stringent that with half a dozen manufacturers on the stream no harm whatever would result to the

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water below, whereas if you multiply the half a dozen to a hundred manufacturers the same standard would admit of damage to the water so that it could not be used below; am I right there?—Yes, you are right there. You must frame a standard for the purpose of dealing with the effluents as discharged into the river. If you begin to deal with the effect of the effluent on volume you come upon treacherous ground. You must deal with the effluents, *per se*, and you must make a standard in regard to these effluents which escape into a river, and not a standard for the river water.

730. Then does it not come to this, that each river must be judged by a separate standard?—No; you must fix the effluent itself, having no regard to the river, to be on safe ground.

731. (*Professor Ramsay.*) Is it not possible, on each river, knowing the manufactures which exist on its banks, so to arrange that the various effluents, to some extent at all events, would neutralise each other?—If they formed a general board, to group all their effluents together to deal with it?

732. Yes?—But then that is a most difficult thing, it is very difficult to get manufacturers to combine to treat the whole of the waters.

733. You mean their position on the stream would not permit of it?—Their position on the stream would not permit of it.

734. (*Sir Richard Thorne.*) Supposing it were practicable that there should be a separate committee for each watershed in the kingdom, do you think it would be practicable to permit each of these committees to define a standard for the streams within their area collectively or separately, such standard to be subject to the approval of some central body; would that, in other words, get over one of the greatest difficulties with regard to uniform standards throughout the whole of the Kingdom?—I think that would be a most difficult thing to arrive at; but by taking each manufacturer on his merits, you have in a nutshell the way to deal with it. For instance, the question is raised, "Is he using the best practicable available means"? Well, then it is for experts to say whether he is or is not; but how can experts decide what standards shall be used on a river; it is a most difficult thing to fix.

735. True?—Supposing you take a small stream with three manufacturers on it, a calico printer, a dyer, and a paper maker, if you fix a standard, the dyer is, say, working with logwood, perhaps he is dyeing all blacks, and you fix a standard for that; then he gives over logwood dyeing and resorts to indigo-dyeing, the thing is entirely altered. You must take the effluent as it leaves the works. You cannot deal with a river and fix a standard for the river, the industries may vary, the processes may alter; one may give up the bleaching department in a dyeworks.

736. Then the position of the river below, in so far as its utility for manufacturing purposes is concerned, will depend not on the character of each separate effluent, but on the number of those effluents?—Quite so; that is so.

737. Then how can you judge each case of a manufacturer apart from the others—so many other considerations seem to be involved?—You remove all the considerations if you only deal with effluents. You have only that consideration to deal with, the best practicable available methods.

738. That may still render the river absolutely useless for another manufacturer below?—If he is using the best practicable and available means.

739. It may still leave the water below useless for another manufacturer?—Yes, that is so, if he is using the best practicable and available means.

740. Then that would be allowing a manufacturer who, if he were using the best practicable and available means, so to foul the river that nobody else could use the water for manufacturing purposes below?—That is so; but what happens? The moment the man below finds that man cannot purify his liquid, he takes him into Court, and he spends so much money that he drives him away, and he may get an injunction against him.

741. We can hardly introduce that as a recommendation of the Commission?—No, but that very often does happen.

742. (*Mr. Killick.*) You expressed the opinion that the way to deal with manufacturing and sewage effluents is to treat the river as a whole, to treat the watershed?—Yes.

743. But in that answer you are only speaking of enforcing the Act of 1876, not of establishing the standards, but merely putting the Act into force?—That is so.

744. You knew something of the Mersey and Irwell watershed before the Joint Committee was formed?—I did; I knew it from 1860 onwards.

745. Was much progress made after the passing of the Rivers Pollution Prevention Act until the formation of the Committee?—Practically there was no progress whatever until the Committee was formed. There were less than half a dozen manufacturers within the jurisdiction of the Mersey and Irwell Joint Committee who had carried out any purification works. Those works had only been carried out by private litigation—manufacturers quarrelling with one another as regards the distribution of the water. Water rights were involved, and certain manufacturers had commenced and got into efficiency certain purification works.

746. The real difficulty, first of all, is with the manufacturers. The authorities wished that all should be treated in the same way?—Yes, that is so.

747. And in the next place, that everybody should be treated alike?—Yes.

748. But if that is left to an individual authority lower down the river, anywhere in the river, it does not happen?—No, that is so.

749. It would be impossible to make any progress by beginning at the top of the stream and forcing the first manufacturer to return the water to the stream in what you describe as a normal condition, because if you did so it would take some things?—You could not make progress. Take them all on some basis and insist on each one using the best practicable and available means, bringing them up first of all before the Local Government Board. They sometimes say: "We do not know what you desire." We are bound, when we go before the Local Government Board inspector, to prove to him that there are reasonable and available means for the purification of the effluent, and the returns Mr. Tatton laid before you show that it has been necessary in some cases to carry it to a further Court; that that is not quite sufficient.

750. That the treatment of the watershed should be continuous?—Yes, and uniform.

751. And uniform?—Yes. I hope I have made myself clear. If you consider the condition of the river—the water into which the effluent flows—you have difficulties at once. We have never recognised that, I do not think, in any of our cases where we have appeared before the Local Government Board, that we have laid before them any analyses of the river water; we have simply taken the effluent itself, *per se*, and brought evidence to show that improvement could be brought about.

752. (*Colonel Harding.*) You said just now that you desire in your district to apply uniformly the test of the best practicable and available means in the case of manufacturers?—Yes.

753. But, surely, yesterday you told us that you varied that considerably; it was the best practicable and available means for the particular manufacturer?—Well, for the manufacturer, yes.

754. So that it was by no means uniform. Then, in the case of a manufacturer who had not room to put down even settling tanks, you would allow him to turn his effluent absolutely untreated into the stream. Another person, in the same trade, who had room, would be called upon by you to put down considerable works for the purification of that effluent?—Yes.

755. Then is that fair to the two manufacturers; it certainly is not uniform?—Of course, a difficulty arises then; the manufacturer is either compelled to leave the district or the sanitary authority must take him into the sewers. Now, with regard to Manchester. Manchester is a densely populated district, and there are many manufacturing works on the banks of the river within the area of the town. Now, in those cases, there are many instances where it was contemplated and thought that the manufacturer would suffer severely by being called upon to purify his effluent by the Mersey and Irwell Joint Committee, and on investigating some of these cases, we found practically that there was no land available for the purpose, but, on the manufacturer applying to the Corporation and by meetings with the Corporation, the Corporation have met manufacturers in a very fair manner, and many of them have got access to the sewers. Take the works of a large colour

manufacturer, employing a great number of men—a thousand men—a most important industry, who turned out daily 250,000 gallons of effluent, he was called upon by the Mersey and Irwell Joint Committee to purify it. He spent an enormous amount of money in tanks and attempts to purify it; his effluent was still unsatisfactory; his effluent was condemned, he was taken before the Court and he was fined, an order made that he should carry out still further works; he called in the best experts that could possibly be obtained, they could do nothing for him, but when he represented his case to the Corporation of Manchester they gave him facilities and access to the sewers, and that source of pollution was removed, benefiting the manufacturers down below. I think these cases are very exceptional; there are very few instances in Manchester, in the whole of Manchester there are not more than ten cases of this sort of difficulty arising.

756. Then I understand that, although you meet with this difficulty and you evidently make allowance for it, at present you agree that manufacturers in a certain area ought to be dealt with uniformly?—Oh, certainly.

757. And you prefer the standard of the most practicable and available means because that is a growing, developing, and improving standard?—Quite so, it is an improving standard, it gives fair play to all manufacturers.

758. The purification of sewage by intermittent filtration on land, I suppose, is of a similar character to the purification of sewage by intermittent artificial filtration?—Yes, just the same.

759. You told us, this morning, that you considered artificial filtration could be worked more simply by untrained labour than land filtration?—Yes, that is so.

760. And that there were means of automatic action, which further simplified the work with artificial filters?—Yes.

761. How is it then that you told us yesterday, in view of the fact that the land and artificial filtration worked in a similar way, and that the artificial filters are, in your opinion, easier to work; you still consider that the results of land filtration are necessarily better than the results of artificial filtration? Assuming even that in the case of artificial filtration the volume of sewage is strictly limited to what is considered to be the safe limit?—Yes.

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762. Why should you not be able, with artificial filters, to attain as good results as by land filtration?—You can get the same result if you put on to the filter the same volume of water.

763. But that was the point I put to you yesterday. Given the safe working limit of artificial filters, ought you not to be able to obtain as good results with artificial filters as with land filtration?—Yes; but the great advantage that an artificial filter has over a land filter bed is that it can pass a larger volume of effluent through, and it can obtain a result which, in my opinion, is satisfactory, but that result is not equal to the result obtained by land.

764. Then why not?—Simply because in the case of land you cannot force the volume of effluent through the land.

765. Yes, but I am assuming that the artificial filter is not forced, that you limit the volume on the artificial filter strictly to what is right and proper?—Yes, well then it would depend on the land. If you were to put ten gallons on a land filter you would get a very high purification; if you put ten gallons on an artificial filter it would depend on the relationship and the porosity, closeness of the filter. If it was an open filter you would not get the same purification as with a close filter.

766. But do you not think that theoretically you could get the same results by artificial filters as from land filtration, seeing that artificial filters are an area specially prepared for the purpose?—You see, if you make an artificial filter, and you make it more porous, capable of taking more water through than a land filter is capable of, you cannot get from an artificial filter area as good an effluent as from land filtration; it depends on its closeness.

767. (*Chairman.*) You are going to give us the results of some experiments?—Yes, of filtration.

768. You are going to send us a short description of the experiments so far?—Yes, the whole that has been done.

Mr. William Henry Wilson, called; and Examined.

Mr. W. H. Wilson.

769. (*Chairman.*) You are Deputy Clerk and Solicitor to the Mersey and Irwell and Ribble Joint Committees?—I am, and have occupied this position ever since those Committees were constituted under the provisions of "The Local Government Board's Provisional Orders Confirmation (No. 10) Act, 1891."

769*. Can you put in a general statement giving an account of the two watersheds and the work of the two Committees?—In the Mersey and Irwell watershed, the population, rateable value, and number of manufactories over which the Committee have supervision are as follows:

	Population.	Rateable Value. £.	s.	d.
7 County Boroughs	1,179,331	5,214,252	5	–
11 Non-County Boroughs ...	294,677	974,411	13	3
62 Urban District Councils ...	639,620	2,674,721	–	1
10 Rural District Councils ...	122,313	867,623	8	–
90	2,235,941	9,731,008	6	4

	Number of Manufacturing Works.	Population.
Rivers Irwell and Roach ...	278	1,015,602
River Irk	43	308,786
River Medlock ...	21	273,550
River Mersey	68	638,003
	410	2,235,941

The district within the jurisdiction of the Ribble Watershed Joint Committee comprises—

County Boroughs	4
Non-County Boroughs	7
Urban Districts	24
Rural Districts	8
Total number of Authorities ...	47

The population of these districts is estimated at 1,000,000 persons, and the rateable value at £3,767,812, and the number of manufactories, 69.

The area of the Mersey and Irwell watershed is 652 square miles, and of the Ribble watershed 544 square miles. The former is drained by the Rivers Mersey and Irwell and their tributaries, the Goyt, Etherow, Tame, Bollin, Roach, Ihr, Medlcok, and the latter is drained by the River Ribble, and its tributaries, the Calder, Hodder, Darwen, and Douglas; the total length of streams being about 453 miles.

Both the authorities are, under the Act of Parliament which constitutes them, sanitary authorities under and for the purposes of "The Rivers Pollution Prevention Act, 1876."

In 1892 it was considered by the Mersey and Irwell Joint Committee that the provisions of the 1876 Act were difficult of application, and they therefore applied to Parliament for further powers. "The Mersey and Irwell Joint Committee Act, 1892," was passed in due course, and received the Royal Assent on the 27th June in that year.

Recent experience, however, has shown that "The Rivers Pollution Prevention Act, 1876," can, in many instances, be administered with extremely satisfactory results; and there is no doubt that some of the provisions of that Act are, from the point of view of an authority like the Mersey and Irwell Joint Committee, superior to some of those contained in the later statutes.

For example—Section 8 enacts that "Every sanitary "authority shall, subject to the restrictions in this Act "contained, have power to enforce the provisions of "this Act in relation to any stream being within or "passing through or by any part of their district, and "for that purpose to institute proceedings in respect of "any offence against this Act which causes interference "with the due flow within their district of any such "stream, or the pollution within their district of any such "stream, against any other sanitary authority or per-"son, whether such offence is committed within or with-"out the district of the first-named sanitary authority."

This is a provision which is not contained in the Mersey and Irwell Act of 1892, or the West Riding of Yorkshire Rivers Act, 1894; and in the case of the

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Mersey and Irwell Joint Committee it has been found an extremely useful provision; for most of the streams, which, after their confluence, eventually become the rivers Mersey and Irwell, rise outside the jurisdiction of the Joint Committee; as, for instance, the Tame in the West Riding of Yorkshire, and the Goyt and the Etherow in the county of Derby; and these streams are very largely polluted by manufacturies and local authorities in those counties. In order to remedy this state of affairs, a considerable number of actions have been taken against these offenders, particularly in the latter county.

"The following shows in tabular form the number of actions which have been taken by the two Joint Committees, and, if required, particulars can be furnished of the effect of the proceedings in each case:—

MERSEY AND IRWELL JOINT COMMITTEE.

"Mersey and Irwell Joint Committee Act, 1892."

Local Authorities.

Number of Authorities Prosecuted	47
Number of Orders obtained	42
Number of Cases withdrawn	2
Number struck out	2
Number dismissed	1
Penalties obtained for non-compliance with the Orders of Court	4

Of the above Authorities, 8 have had 1 extension of the Order of Court.

Of the above Authorities, 3 have had 2 extensions of the Order of Court.

Of the above Authorities, 4 have had 3 extensions of the Order of Court.

Of the above Authorities, 2 have had 4 extensions of the Order of Court.

Of the above authorities, 1 has had 5 extensions of the Order of Court.

Of the above Authorities, 1 has had 8 extensions of the Order of Court.

Manufacturers.

Application has been made to the Local Government Board for leave to take proceedings in...	33	cases.
Consent given by Local Government Board in	30	,,
Consent not given by Local Government Board in	2	,,
Consent withheld on Joint Committee's own application in	1	,,

Proceedings taken against 18 firms or manufacturers.

Orders of Court obtained against 17 firms or manufacturers.

Case dismissed, 1 firm or manufacturer.

Penalties were obtained against 1 firm for disobeying the Order of Court.

"Rivers Pollution Prevention Act, 1876."

Local Authorities.

Under this Act proceedings were taken by the Joint Committee against two authorities outside their jurisdiction (Glossop and New Mills), and Orders of Court were obtained in each case.

The Joint Committee have also taken proceedings under the Act against three Local Authorities within the watershed, namely, the Salford Corporation, Stockport Corporation, Cheadle and Gatley Urban District Council, and have obtained an Order of Court in each case.

Manufacturers.

Applications to Local Government Board for leave to take proceedings	5
Consent given by Local Government Board ...	5
Proceedings taken	2
Orders of Court obtained	2

Solid Pollution.

Authorities fined	4
Employees fined	3
Manufacturers fined	7
Employees fined	12

RIBBLE JOINT COMMITTEE.

Local Authorities.

Proceedings have been taken against 20 Local Authorities.

Orders obtained against 12 Local Authorities.

Cases withdrawn, 6 Local Authorities.

Adjourned *sine die*, 2 Local Authorities.

Penalties for non-compliance with the Orders of Court have been obtained in two cases.

Manufacturers.

Applications to Local Government Board for leave to take proceedings	26
Consent given by Local Government Board ...	24
Consent refused by Local Government Board (granted upon a second application)	1
Decision pending	1
Proceedings taken	7
Orders of Court obtained	5
Pending	2

Solid Pollution.

Proceedings taken in 4 cases.

Order of Court obtained in	1
Withdrawn upon given undertaking	1
Dismissed (appeals now pending)	2

From experience gained in the before-mentioned actions, it would appear that the method or methods of treating and disposing of sewage to be adopted by a local authority should, in certain instances, be varied by the fact as to whether or not, and (if so) in what proportion the liquids from factories or manufacturing processes are admitted into the sewers. In this matter, Section 7 of "The Rivers Pollution Prevention Act, 1876," enacts as follows:—

"Every sanitary or other local authority having sewers "under their control shall give facilities for enabling "manufacturers within their district to carry the liquids "proceeding from their factories or manufacturing pro- "cesses into such sewers:

"Provided that this section shall not extend to com- "pel any sanitary or other local authority to admit into "their sewers any liquid which would prejudicially affect "such sewers or the disposal by sale, application to land, "or otherwise, of the sewage matter conveyed along "such sewers, or which would from its temperature or "otherwise be injurious in a sanitary point of view:

"Provided also, that no sanitary authority shall be "required to give such facilities as aforesaid where the "sewers of such authority are only sufficient for the "requirements of their district, nor where such facili- "ties would interfere with any order of any court of com- "petent jurisdiction respecting the sewage of such "authority."

It will be observed that no such similar enactment is contained in "The Mersey and Irwell Joint Committee Act, 1892," or "The West Riding of Yorkshire Rivers Act, 1894," and undoubtedly wisely so; for in the first place it would appear that even with the provisions of the Rivers Pollution Act in force it is extremely difficult to compel a local authority to admit the liquids proceeding from the factories within their district into their sewers in case they are unwilling to do so (*vide* Peebles *v.* Oswaldtwistle Urban District Council).

In some instances, no doubt, as in the case of Wolverhampton and other districts where there are large galvanising works, the admission of such trade effluents into the sewers has caused an enormous amount of trouble and expense to the authority in treating their sewage. In this matter, to quote further instances, Manchester and Salford may be given as typical examples. Orders of Court have been obtained against both these authorities at the instance of the Mersey and Irwell Joint Committee which have not as yet been obeyed, and one of the principal arguments to the Joint Committee for this reason, apart from the requirements of the Local Government Board as to the purchase of an adequate area of land for the filtration of the sewage, is generally that, owing to the enormous volume of manufacturers' effluents which comes down to their respective outfall works, in an intermittent manner, and of a character varying from hour to hour, this places great difficulties upon the authorities to know exactly how they are to treat their effluent, for they state that a certain amount of precipitant added during one given period of time which would probably then give a good

result, has perhaps at the next moment very little value from a purification point of view owing to the change in the nature and flow of the effluent.

It appears to be a fact, however, that certain manufacturers' waste liquor might, with advantage to the firm concerned, and in particular to the Conservancy Boards and other Authorities which are charged with the prevention of Rivers Pollution, be admitted into the different public sewers, and this particularly refers to the effluents coming from fellmongers, tanneries, and breweries. The constituent parts of these, from a chemical point of view, appear to closely resemble those of domestic sewage, and, as they can be purified by practically the same method of treatment, it would seem advantageous for facilities in that direction to be given. In the Ribble Watershed, the town of Colne may be stated as one which has recently allowed the tanners of the district to couple up with the outfall works and have their effluents treated there—a step which has caused an immense improvement to the river, as none of these works had anything like satisfactory purification works themselves, or, in fact, facilities for putting the same down. In the case of the Borough of Clitheroe also, in their new sewage scheme, they have permitted the various breweries to be connected with the sewers.

Standards.

With reference to the question of Standards, the battle raged thereon appears to be one for chemical more than for legal opinion; but it will be readily understood that, in the large number of cases which have been brought in both watersheds during the past six years, the question has been raised over and over again in different forms, and from this it is evident that it will be extremely difficult to fix an arbitrary Standard, even such a one as that suggested by the late Rivers Pollution Commissioners, and for two reasons:—

1. That some works, which are advantageously situated both as regards having land and other facilities for the erection thereon of efficient purification plant, do obtain a better result than the Standard proposed to be fixed by the said Commissioners.
2. That there are a large number of manufacturers, and in fact may be of local authorities who, owing to the want of space, tank room, and other facilities, are unable to attain to such a proposed degree of purity.

With regard to the methods of treatment, I would point out that the reports which Mr. Tatton and others have presented show that where suitable land can be obtained, which, in the part of England referred to is only to be done in isolated cases, no doubt the best results can be thereby gained from a purification point of view. Of this the gentleman referred to will be better able to speak than I am, but I should like to state here the difficulty which the two Joint Committees have in many instances been met with where land has been purchased, namely, that at one time many Authorities sublet the farms which have been obtained for irrigation purposes. Of course these, as soon as they were in the hands of tenants, were farmed more for profit than for sewage disposal, and recent instances may be given in proof of this in the case of the Urmston and Flixton Joint Drainage Committee, who, during the past month, while the farmer to whom they had sold the hay for £7 has been getting and stacking the same, discharged the raw effluent without treatment into the Manchester Ship Canal, and they were therefore summoned before and fined by Mr. J. M. Yates, the Stipendiary Magistrate sitting at Manchester, for this very offence. That is a case within the Mersey and Irwell Watershed. In the Ribble Watershed a similar instance occurred last month, when a deputation from the Ormskirk Urban Council only avoided proceedings being taken against them by undertaking at an early date to obtain the control of their land by taking it out of the hands of the tenant and using it in a proper manner for the disposal of sewage.

The Consulting Sub-Committee of the Mersey and Irwell Joint Committee, who have charge of the steps to be taken with reference to the pollution arising from sewage works, also presented the following report to the Joint Committee, on the 2nd November, 1896, upon the subject:—

Supplement to the Report of the Mersey and Irwell Consulting Sub-Committee.

The Consulting Sub-Committee presented the following supplementary Report:—

"As there seems to be some misapprehension with regard to the principles upon which the Mersey and Irwell Joint Committee are acting, and their methods of applying those principles, the Sub-Committee consider it advisable to make a short statement. *Mr. W. H. Wilson.* 13 July 1898

"First, it is desirable to call attention to the fact that no definite standard of purity has been adopted, and the members of the Joint Committee, on reference to the proceedings, will find that so far back as December, 1891, on the recommendation of Sir Henry Roscoe, a resolution was passed stating that it was undesirable to define the maximum amount of pollution to be allowed, but to insist upon the best practicable and available means being used in each case, whether a Sanitary Authority or a Manufactory.

"Further, in the proceedings of November 5th, 1894, page 312, it will be found that Sir Henry Roscoe again stated 'it must be distinctly understood that the standards named are only adopted for the purpose of criticising and comparing the results in these particular cases, and must not be taken as definite standards."

"Up to the present time the Sub-Committee have always acted upon those principles, and have had before them the results of over 1,000 analyses of samples of sewage effluents taken under varying circumstances and conditions from the sewage works in the watershed. It is clear from the consideration of these analyses that in order to render the water fit to go into the stream by the removal of the soluble putrescible organic matter, in other words, to prevent secondary decomposition, the amount thereof must be reduced to the limits referred to in the November Report of 1894.

"These limits of impurity are based upon experimental evidence proving that an effluent below or up to them would not putrefy when discharged into small streams or into sluggish waters, such as the Manchester Ship Canal, but above them putrefaction would arise, and it may be observed that at all sewage works in the watershed where only chemical treatment is adopted the effluent is almost invariably above, and, on the other hand, where sewage works adopt filtration the effluent is below those limits.

"The Sub-Committee have never laid down a hard and fast line with regard to the use of any particular kind of purification plant, and have accepted effluents from precipitation plant alone where they have proved satisfactory. Precipitation processes, as a rule, can only be relied upon as capable of removing at the utmost two-thirds of the organic matter, whereas in good filtration methods from four-fifths to nine-tenths of the whole can be removed.

"Before proceedings are directed other chemical details and investigations, in addition to the limits of impurity, are carefully considered.

"It has been suggested that effluents from precipitation tanks alone should be accepted. To do so would, in the opinion of the Sub-Committee, render the work of the Joint Committee futile and its continuance unnecessary. The object for which the Joint Committee was constituted was for the express purpose of cleansing the rivers within its district from their polluted and filthy condition, and if that purpose is to be limited to the removal of the solids in suspension, leaving the soluble putrescible organic matter liable to secondary decomposition present in the effluents, not only will the provisions of the Rivers Pollution Acts be contravened but the condition of the rivers must for ever remain prejudicial and hurtful to the health and well-being of the inhabitants in the watershed.

"T. W. KILLICK,
"Manchester, 2nd November, 1896. Chairman."

Upon this report the following resolution was passed:—

"*Resolved*—That the same be adopted and be printed with the proceedings, and that copies thereof be sent to all the Local Authorities and Manufacturers in the watershed."

Artificial Treatment.

The question of the treatment of sewage by precipitation and subsequent filtration in filters, other than of land, and of different constructions has been considered by the Joint Committee from time to time, and on the 6th July, 1897, they forwarded the following reports to the Local Government Board, and requested them to receive a deputation upon the subject:—

"10, Bramham Gardens,
"Wetherby Road, S.W.,
"May 26th, 1897.

"To the Consulting Sub-Committee.

"Gentlemen,

"I have pleasure in reporting to your Committee as to the efficiency of the results obtained in the treatment of sewage by precipitation and artificial filtration.

"I am of opinion that the adoption of artificial filters is a move in the right direction, especially in the case of large

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towns having difficulties in acquiring sufficient area of land and of a suitable character for the purification of its sewage.

"Land filtration, so far as the chemical results are concerned, is superior to artificial filtration. Unfortunately, however, the volume of effluent that can be treated permanently on land is small as compared with the volume that can be filtered by artificial filters.

"I have had the advantage of carrying out important trials, extending over a period of seventeen months, with filters made both of cinders and of coke for the Rivers Committee of the Manchester Corporation, and the results have been of a satisfactory character. The effluent submitted to filtration had previously been treated with milk of lime and copperas. The volume of such effluent, which an acre of filter was able to deal with continuously, was about 800,000 gallons per day. It remains, however, to ascertain how long these filters will work satisfactorily before requiring renewal of a part or the whole of their contents, and this is a cardinal point.

"Artificial filters have, in some instances, been adopted at sewage works under the jurisdiction of your Committee, and the failures which have frequently attended their use are traceable to the non-compliance with the conditions which are essential for successful and permanent purification. Quoting from my report to the Rivers Committee of the Manchester Corporation, dated April, 1896, I said: —'The conditions essential for successful purification by filtration, viz., the conversion of the organic carbon and of the organic nitrogen in the sewage into inorganic matter, have long been recognised and advocated, but, I am sorry to add, generally ignored in practice.'

"The Rivers Pollution Commission, 26 years ago, pointed out that in filtration, whether through sand, gravel, chalk, or soil, or a mixture of chalk and sand, it was essential that the atmospheric oxygen should have frequent and free access to the interior of the filter, and that the effluent should flow freely off from the bottom of the filter, so that as the last portion of each dose of sewage water sinks into the filter it may draw atmospheric air into the pores of the material from the surface downwards. The subsequent researches of Messrs. Müntz and Schloesing in France, and of Professor Warington in this country, have shown that purification, as defined above, is brought about by the intervention of micro-organisms. Professor Warington has also pointed out (14 years ago) that sewage contains the micro-organisms necessary for its own destruction, and that, under favourable conditions, these may be so cultivated as to effect the purpose, provided the filter is well supplied with air requisite for the discharge of their functions, and also that sufficient lime be present to combine with the nitric acid, otherwise the process of nitrification is stopped. The results of the experiments made by the American chemists (1891) of the Massachusetts Board of Health confirm the above statements, for they state that—'The purification of sewage by intermittent filtration depends upon oxygen and time: all other conditions are 'secondary. Temperature has only a minor influence: 'the organisms necessary for purification are sure to establish themselves in a filter before it has long been in use. 'Imperfect purification for any considerable period can 'invariably be traced either to a lack of oxygen in the pores 'of the filter, or to the sewage passing so quickly through 'that there is not sufficient time for the oxidation processes 'to take place. Any treatment which keeps all particles 'of sewage distributed over the surface of sand particles, 'in contact with an excess of air for a sufficient time, is 'sure to give a well oxidised effluent, and the power of any 'material to purify sewage depends almost entirely upon 'its ability to hold the sewage in contact with air. It 'must hold both sewage and air in sufficient amounts. 'Both of these qualities depend upon the physical characteristics of the material. The ability of a sand to purify 'sewage, and also the treatment required for the best 'results, bear a very close relation to its mechanical 'composition.'

"The difficulty of the subject lies not of course with the smaller authorities. Thus out of 54 Sanitary Authorities reported upon this month, 37 are satisfactory; and all of these, with the exception of Oldham, which is not completely connected up, are small ones; and in these, land filtration (16 cases), or artificial filtration (19 cases), or tank precipitation alone (2 cases), have yielded a satisfactory result. It is where we have to deal with large populations that the difficulty becomes great, because the data upon which conclusions as to the practical and permanent efficiency of artificial filtration on a large scale is yet wanting. To obtain such data, I advised the Rivers Committee of the Manchester Corporation to carry out artificial filtration on a considerably larger scale than had hitherto been the case.

"HENRY E. ROSCOE.

"Manchester,
"May 26th, 1897.

"To the Consulting Sub-Committee.

"Gentlemen,—

"In accordance with a resolution of the Committee that a special report be prepared on the results obtained by the treatment of sewage by precipitation and filtration at the various works in the watershed where this method of treatment is adopted, I beg to report as follows:—

"The total number of Authorities using this method of treatment represents a population of about 172,000, and the results obtained, as gauged by the analyses of samples taken, are satisfactory in about 86,000, or one-half of the total; this seems a small proportion, but if the matter is looked into it is evident that the filters which have failed have had little chance of success from the outset, either in consequence of the tank effluent which is put on them being insufficiently precipitated, in consequence of the filters being badly constructed or mismanaged, or in consequence of the area being too small to deal with the volume of sewage. One or other of these reasons has, in my opinion, been the cause of failure in every case where precipitation and filtration has been attended with unsatisfactory results.

"The experiments on a considerable scale which have been made by Sir Henry Roscoe at the Manchester works, by Mr. Dibdin in London, and by Mr. Corbett in Salford, clearly demonstrate the possibility of treating the sewage of large towns by artificial filtration if a sufficient area of filter beds be used.

"There seems, therefore, to be ample evidence to show that if filters are constructed to conform with the principles which have been laid down that satisfactory results may be obtained.

"It is, however, necessary not to lose sight of the fact, which would, I think, be supported by high scientific evidence, that if suitable land is obtainable, filtration through land is the most permanent and satisfactory method of treatment. This is fully borne out by the experience on the Mersey and Irwell Watershed, where the proportion of works with land treatment giving satisfactory results is considerably higher than those with artificial filtration.

"Failure with land treatment has, in several cases, taken place, but these failures again are attributable either to the land being unsuitable to the purpose, to its being improperly laid out or badly managed, or to the volume of sewage turned on to it being greater than it can deal with.

"The reasonable view to be taken of the matter seems to be that instead of any hard and fast rule being laid down, each case should be treated on its own merits; that if suitable land can be obtained it should be used, but that, if it cannot be got artificial filters should be sanctioned, but with stringent restrictions as to the volume of sewage allowed on a given area.

"I am,
"Your obedient Servant,
"R. A. TATTON."

On the 21st of July the deputation appointed for that purpose duly attended before the Local Government Board, and no doubt full details of the interview have been given to the Commissioners by Mr. Tatton.

Owing to the short time at my disposal, and the pressure of other work, it has been impossible to go into minute details of the various legal chemical and technical points raised with reference to what are and what are not the best methods of treating and disposing of the liquid from manufacturing processes consistently with due regard to the requirements of the existing law; and if further information is wanted upon this subject I shall be pleased to draw comparisons of the various points raised as before indicated, and to show from a legal standpoint what decisions have been given in Courts of Summary Jurisdiction, Courts of Quarter Sessions, County Courts, Queen's Bench Division, and Divisional Courts upon this subject, for there is no doubt that the decisions vary according to the relative facts in each case.

770. What is that case, Peebles *v.* Oswaldtwistle Urban District Council?—That was a case, my Lord, by which a certain firm of manufacturers, named Peebles and Co., who carry on the business of white paper mills, White Ash, within the district of the Oswaldtwistle Urban District Council, sought to compel the Council to admit the effluents from their works into the sewers. The matter was first of all taken before the late Mr. Justice Charles, and he held that an action by mandamus would lie against a local authority to give facilities for the admission of a manufacturer's effluent into the sewers. That, however, was appealed against by the authority, and the Court of Appeal held that Mr. Justice

Charles was wrong, and that no mandamus would lie, but that Messrs. Peebles had the remedy prescribed by the Act of 1875, namely, to go to the Local Government Board and report the Council for not having properly provided the district with sewers to provide for the drainage. That decision was recently practically upheld by the House of Lords.

771. It has been upheld by the House of Lords?—It has been upheld by the House of Lords.

772. There is no question of appeal there?—There is no question of appeal there.

773. Then is it settled that the Urban District Council, or the proper authority in such cases, must provide a sewer for the sewage to go into?—No, my Lord. Really, what the Courts have decided is this, that in case it is alleged that a local authority have not, under the provisions of the Public Health Act and the 1876 Act, provided proper sewers for a district, the proper authority to see that they should do so, and to whom they should be reported, is the Local Government Board.

774. I see?—The Act of 1875 provides that an authority which has not made sufficient provision for the sewage of the district shall go to the Local Government Board.

775. I take it then from the evidence generally that if the best practicable and reasonable available means are adopted, the Committee is usually satisfied?—Yes. That is to say, upon the report of Mr. Tatton and Mr. Scudder, that it is brought in the first place before a chemical sub-committee, who have the charge of the manufacturing cases, and the consulting sub-committee of local authorities, and if they report that they are satisfied no further action is taken by the Board.

776. And the Committee endeavour to get on amicably with the manufacturers?—That is so. I think I ought to say here, if you refer to the figures, my Lord, that I have given, you will see that in Mr. Tatton's watershed there are 410 manufacturers, and out of that 410, owing to the conciliatory way in which the manufacturers have met the Committee, it has only been necessary to apply to the Local Government Board in thirty-three cases, whereas in the case of local authorities, out of ninety local authorities in the same watershed, we have taken proceedings at the present time and obtained orders against no fewer than forty-seven. That shows the difference in the attitude of the authorities as against the manufacturers.

777. You sent me a note of a case which is to be tried?—Yes.

778. Where the point is whether a manufacturer who is said to have done his best is to be allowed to let his effluent go into the river?—That is so, my Lord.

779. Is it a river or the sewer?—It is a case of a river. It is the case of Almond and Co., paper makers, of Darwen. The proceedings were originally taken under the Rivers Pollution Act, 1876, because that is the only Act which the Ribble Joint Committee is able to enforce. They have not the same Act as the Mersey and Irwell Joint Committee. We entered a Plaint in the Blackburn County Court, and, under the provisions of the Act of 1876, it was moved to the High Court, and the trial will commence before a judge and special jury at the ensuing Manchester Assizes.

780. What is the case called? What is the form of the case? Are the Ribble Joint Committee parties to it?—Yes, the Ribble Joint Committee are the plaintiffs. They are a committee constituted in the same way as the Mersey and Irwell Joint Committee, and under the same powers of the Local Government Board, and they are the plaintiffs and Messrs. Almond and Co. are the defendants. I may say Messrs. Almond and Co. raise a point which I think was put to Mr. Scudder. Messrs. Almond and Co. did apply to the Corporation of Darwen to admit them into their sewers. The Corporation of Darwen absolutely refused. Then Messrs. Almond and Co. raised the point that they are using the best practicable and reasonable available means, while the advisers of the Ribble Committee are of opinion that they were not, and hence the High Court proceedings. It is the first case, I believe, where the whole matter in detail will be gone into and no doubt it will be taken, certainly by the plaintiffs, up to the highest courts to determine what this really means—what the best practicable and reasonable available means are.

781. I see, then the contention of the Committee is that the best means are not being used?—That the best means are not being used, and that, really, when the proceedings were taken, the firm were polluting the stream, grossly polluting a stream under the alleged protection of the clause. Since proceedings have been taken—at the present time I think Mr. Naylor will be able to give you some information—a sample was taken in the presence of Dr. Dupré, who was one of our witnesses, which contained on analysis not less than twenty grains of copperas per gallon. That is a point raised in your question put to Mr. Scudder, is it to be allowed that a manufacturer can, by putting in such an enormous amount of copperas, get rid of all suspended solids and yet add as much as twenty grains per gallon, with an effluent varying from 175,000 to 200,000 tons into a stream—the river Darwen, which is very little wider than this table.

782. Will the case be based on the ground that they are not doing their best, or will it be contended that even if they were doing their best, their best is so very bad?—I think we shall take that in the alternative, my Lord.

783. You will try it?—Those are the two points that I intend to raise.

784. Will that be quite a new point; I mean will that be raised for the first time?—As far as I can gather it will be raised as to what the best practicable and reasonable available means are. Messrs. Almond have put down, I may say, a small tank, a circular tank which originally was designed to hold 25,000 gallons. Well, they found difficulties, or alleged there were difficulties in getting rid of the sludge, and what they say is this: "We agree to 13,000 gallons; we have got no more room now, and we are unable to treat this 175,000 to 200,000 gallons any better than by a tank for 13,000." Well, we say: "You cannot do it; it is impossible in this tank, but it is the case that you have two or three cottages, let at 2s. 6d. a week, adjoining this tank." We say, sooner than be allowed to pollute the river, we shall try to compel you to pull these cottages down and put up further purification plant; Messrs. Almond say that is unreasonable; the law did not intend any such thing. That is one of the points.

785. (*Mr. Killick.*) Have you found, either in the Mersey and Irwell watershed, or the Ribble watershed, that the objection or the plea of the manufacturer that he is using the best practicable and available means has practically impeded the work?—No, I have not.

786. It is a theoretical matter?—This is the very first instance.

787. (*Colonel Harding.*) I wanted to ask Mr. Wilson whether he considered the definition of the rights of the manufacturer were sufficiently clear. The law now states, I think, that he can compel a local authority to take a trade effluent if there is a sewer, if the sewer is large enough, and if the trade effluent is not of a character to injure the sewer, or prejudicially affect the treatment of the sewage. That is so, is it not?—That is so.

788. Has any difficulty arisen with regard to the interpretation of the law on these points?—The law, on these points, has only been raised and taken to the High Court in that case, as far as I know, of Peebles *v.* Oswaldtwistle Urban District Council.

789. Then you have not found difficulty on the part of the local authorities as to whether they should or should not take trade effluents?—I think, with the exception of Manchester and one smaller authority, all the local authorities in the two watersheds practically decline to take trade effluents; it is the exception rather than the rule.

790. On what ground?—On the ground that the capacity of the sewers is not large enough, and that the effect of discharging trade effluents, particularly in a rural district, into the sewers is such as to prevent them dealing properly with the sewage.

791. Then you think the law is quite sufficiently clear on that?—I think the law is sufficiently clear, and I think that it is very necessary to protect the local authority in the way intended by the 1876 Act.

792. (*Dr. Russell.*) I see, at page 5, you refer, at the bottom, to a difficulty the Joint Committee have had from land purchased for the purpose of use for irrigation being sublet?—Yes, that is so.

793. Do you think it would be advantageous to have some statutory provision to prevent that?—I certainly do, sir. I think it is very essential, and I think ex-

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perience has shown it, that in all cases in both watersheds, where land has been let to a tenant, invariably there have been bad results, and in many instances where the authorities have taken that very farm into their own control they have been able to get very satisfactory results. I think, therefore, that if there is to be any change in the legislation, that power ought to be given either to similar Boards or to the Local Government Board, to compel the local authority to retain possession of the land itself, and to treat the sewage on the land, and that they should not be allowed to farm the property.

(*Major-General Carey.*) That is what we do require at present.

(*Chairman.*) Do you require that?

(*Major-General Carey.*) Always, that the authority shall treat it themselves. Where they have rented it we require that the lease shall be determined, or determined as soon as possible; that is of late years.

(*Mr. Killick.*) That will only be if they apply for more money.

(*Major-General Carey.*) Whenever we find that a sewage farm has been let to a tenant without the knowledge of the Board; it certainly is without the knowledge, probably of the Local Government Board, we require that the tenancy shall be determined, and that the authority shall take the farm into their own hands and manage it themselves.

(*Chairman.*) Have you got power to do that, if they do not apply to you for money?

(*Major-General Carey.*) We take the first opportunity we have when they want some loan connected with sewerage and sewage disposal.

793* (*Mr. Killick.*) There must be that application before you can exercise that power. Mr. Wilson's suggestion goes beyond that?—I would suggest that, without an application for a loan in some case, some statutory authority, like the Local Government Board or some other Board, should have power to take such action. We have done it by pressure on the Mersey and Irwell Watershed, and I think the Urmston and Flixton Joint Drainage Committee case is the only one where the authorities themselves do not farm the land.

794. (*Dr. Russell.*) I think, Mr. Wilson, at the bottom of page 5, it is stated that in the Ribble Watershed a similar instance occurred last month, when a deputation from the Ormskirk Urban Council only avoided proceedings being taken against them by undertaking, at an early date, to obtain the control of their land by taking it out of the hands of the tenant and using it in a proper manner for the disposal of sewage. You also put a stop to sub-letting in an indirect way by threatening a prosecution?—That is the way we do it, sir; we threatened them last month.

794*. Instead of the indirect methods referred to, you think there should be statutory power?—I think there ought to be; it would be simpler, and would save time.

795. (*Professor Foster.*) There appears to be a slight difference between the evidence of Mr. Adrian and Mr. Wilson as to the case of Peebles *v.* Oswaldtwistle Urban District Council. From Mr. Adrian's evidence it would appear to me that the decision of the House of Lords was given on the question as to whether the Local Authority must make such sewers as might be necessary for effectually draining their district. I think I understood from Mr. Wilson's evidence that it was a question of the sewage, as to admitting the sewage into sewers?—Perhaps I was not quite clear. What I meant to say was that the principle really decided by the Local Government Board, or the greater part of the principle decided by the Board, was as to the method of procedure, that is, as Messrs. Peebles alleged, the Oswaldtwistle Urban District Council had not made proper provision, or ought to take them into their sewers, they should have gone to the Local Government Board, as indicated by the Public Health Act, and that the action by mandamus would not lie.

796. But Mr. Adrian's evidence is that the two questions were left to Mr. Justice Charles: (1) that the Local Board should be compelled to make such sewers as might be necessary for effectually draining their district for the purpose of the Public Health Act, 1875; and (2) to give facilities for enabling the plaintiff to carry liquid from his factories or manufacturing processes into the sewers under their control?—Yes.

797. And then he goes on to say, upon the first point, the Urban District Council appealed against Mr. Justice Charles. The Court of Appeal gave judgment in favour of the Urban District Council, holding that the case came within the rule that, if a new obligation is imposed by statute, and, in the same statute, a remedy is provided for non-fulfilment of the obligation, that is the only remedy, and that, accordingly, the remedy by complaint to the Local Government Board under Section 299 was a bar to the application for a mandamus. The decision of the Court of Appeal was affirmed by the House of Lords. And the decision of the House of Lords was given on that?—The decision of the House of Lords was given on that, but the main part of the case, as I understand it, I am speaking from memory, the main part of the case was on a method of procedure.

798. There appeared to me to be a discrepancy between your evidence and that of Mr. Adrian, and I thought it would be better to have it cleared up?—Certainly.

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Mr. WILLIAM NAYLOR, A.M.I.C.E., F.C.S., Chief Inspector of the Ribble Joint Committee, called; and Examined.

799. (*Chairman.*) You are Chief Inspector of the Ribble Joint Committee?—I am.

800. The Ribble Joint Committee was formed when?—In 1891.

801. Have you anything to hand in?—I hand in the transcript of the shorthand notes taken at the inquiry.

802. Are these the shorthand notes on which the Committee was founded?—That is so.

803. And then do you hand in also your instructions for the preparation of a special report on the "treatment and "nature of manufacturers' waste effluents"?—They are contained in the proceedings of the Ribble Joint Committee, December, 1892.

804 (*Mr. Killick.*) Have there been any annual reports to the Ribble Joint Committee; the reports showing the work done will be sufficient, we do not need the detail?—These are the annual reports. Of course, I do not wish to press them upon you. I can leave them here; they need not be formally put in.

805. Is there any summary?—No; there is no summary. The particular instruction referred to was given me in December, 1892, the instruction for this particular report on the treatment and nature of manufacturers' waste effluents.

806. (*Chairman.*) You received instructions from them to prepare a report?—I did.

807. And you prepared that report?—I prepared that report, and twelve copies have already been forwarded to the Secretary to this Commission. This is a single copy of the special report. (*Copy of report handed in.*) Appendix No. 2.

808. This report, as I understand, was followed by a Conference between the manufacturers and the Ribble Joint Committee?—It was. The Conference was for the purpose of meeting the manufacturers, to see if some agreement could not be come to as to the particular works which it was thought desirable to be carried out by manufacturers. In the case of the cotton trades, it was eventually agreed between their representatives and the Ribble Joint Committee that certain methods of treatment should be adopted, and those methods of treatment are embodied in the agreement which is signed by the whole of the representatives of the cotton trade in the Ribble Valley.

"At a meeting of the Joint Committee to enforce the provisions of "The Rivers Pollution Prevention Act, 1876," in relation to parts of the River Ribble, held at the County Offices, in Preston, on Monday, the 9th day of October, 1893.

"PRESENT—

"Sir John T. Hibbert, K.C.B., M.P., Chairman,
"Etc., Etc., Etc.

"*Resolved.*—1. That in respect of effluents, the liquors to be treated, and the mode of their treatment, shall be separately considered in the case of each different trade and manufactory.

"*Resolved.*—2. That in the case of Bleachers, Calico Printers, and Dyers, the general principle to be adopted

shall be treatment by subsidence, precipitation, or filtration of the refuse, either singly or combined, in such a manner as to obtain an effluent which will fulfil the requirements of 'The Rivers Pollution Prevention Act, 1876."

"*Resolved.*—3. That one year be generally allowed to these manufacturers to carry out and complete the necessary works for the treatment of their effluents; but that at the end of six months the Joint Committee shall have the right to re-consider the position of any case where no *bond fide* steps have been taken to proceed with the works.

"*Resolved.*—4. That upon each Manufacturer expressing in writing his adoption of the foregoing conditions no proceedings be taken against him for one year from the date hereof, except as above specified.

"I hereby accept and undertake to carry out the foregoing conditions.

"(Signed)

809. And with the chemical trades was there an agreement made?—In the case of the chemical trades also a general agreement was entered into, which was signed by them all, without exception. This is a copy of that agreement:—

"AGREEMENT.

"We

hereby undertake that, in order to prevent any further pollution of the stream by the effluent from our works, the general principle we will adopt will be treatment by subsidence, precipitation, or filtration of the refuse, either singly or combined, in such a manner as to obtain an effluent which will fulfil the requirements of 'The Rivers 'Pollution Prevention Act, 1876'; and we further undertake that, in consideration of the Ribble Watershed Joint Committee not taking proceedings against us before the day of next, we will construct and have in operation works as before-mentioned for the treatment of our effluent.

"Dated the day of 1894.

"(Signed) ."

810. And with the paper trade you came to no general agreement?—In the case of the paper trades no general agreement was arrived at. The Committee then decided to consider each particular case upon its own merits, and I was instructed to draw a report dealing with each paper mill in the valley separately. That report was presented in November, 1893.

811. Speaking generally, those agreements have been carried out, I suppose?—Yes, they have.

812. With the cotton trades and the chemical trades?—With the cotton trades and the chemical trades those agreements were adhered to.

813. And have been carried out ever since?—Yes.

814. And with the paper trades, you dealt with each case separately?—We dealt with each case separately.

815. And you do still?—Well, eventually all, with the exception of one, did sign a modified agreement, which I also hand in.

"AGREEMENT.

"We

hereby undertake that, in consideration of the Ribble Watershed Joint Committee not taking proceedings against us before the day of next, we will construct and have in operation by that date works for the purification of our effluent.

"Dated the day of 1894.

"(Signed) ."

In the case of the cotton trades there was an Association. We acted really with the Association. In the case of the paper makers we dealt with each firm separately, and only one, against which an action is now pending, declined to sign this agreement, or to enter into any agreement.

816. The Committee has gone on, and there is an annual report of its progress, I suppose?—The annual report has only been presented in March, 1898, and March, 1897. Previous to that time, we had not presented an annual report. The Committee meets monthly, and a report was presented each month, but in 1897 and 1898 a report was presented, which does, as a matter of fact, show the progress made generally during the previous years. That report appears in the report for the month of March, 1898, and in the report for the month of June in the year 1897.

817. Had you any special difficulties attending the working of the 1876 Act?—The special difficulties which I thought of suggesting to the Commission were first with regard to what is meant by the best-known reasonable means. Of course, the manufacturers thoroughly understand the Act of 1876. They have given a great deal of attention to it, and my experience is that there is generally a difference between the manufacturer and the inspector as to what the best reasonable means really are.

818. I do not know that I need trouble you to go very much into that question now, because as I understand from Mr. Wilson, a very important legal case is now going to take place within the next few days, promoted by the Ribble Joint Committee?—They have a case pending which is one of perhaps a dozen that have been tried, but every case that has been taken to the County Court is really tried on the question as to when a manufacturer has done sufficient.

819. But this case is going to be tried at the Assizes, and it will throw a great deal of light on what view the Courts hold as to what the best reasonable means are?—Quite so.

820. Then the next point in your evidence is standards. You say most of the outlets were constructed before the passing of the Act, thus bringing the owners within the "best known reasonable means" clause. We do not want, you know, to have exactly the same evidence over again. We have heard a great deal from the other gentlemen, and I will just run through this and see whether you have any special note. You have the difficulty of fixing standards. Well, of course, that we know. The effluents from different trades differ in composition. That we know. The effluents from different factories in the same trade differ according to the different speciality produced. That we know. Effluents from one and same factory differ according to varying speciality produced, and according to point of time in process of manufacture. The facilities for treatment vary according to locus of the factory. Your experience is that tentative standards could be fixed for each trade with regard to solid matter in suspension, alkalinity or acidity, free chlorine and soluble sulphides, and in the case of sewage effluents with regard to the amount of solid matter in suspension, albuminoid ammonia liberated and oxygen absorbed. Now, do you wish to enlarge on that at all?—No, I have no desire to enlarge on anything. That is my opinion. I have met nothing in my experience which I think would prevent a tentative standard being put into operation with regard to these matters.

821. And you think that the standard would not only be possible in regard to these matters but desirable?—I think it is desirable. As matter of fact, before an inspector can make a complaint he must have in his own mind some idea of what he is to complain about, and my reports to the Ribble Joint Committee are, at any rate, based on a standard which is in my own mind, and in the minds of the Committee, too.

822. Then the next point is dilution of effluents with river water, and your experience is that this is often done with the object of obtaining an effluent giving a good result on analysis. In what way is this managed; I mean, does a manufacturer carry river water up to his works and pour it in on his trade refuse or what?—The case I have in my mind—and there are other similar cases—is where a paper manufacturer has a lodge which he uses for condensation purposes. Of course, a stream is continually flowing through that lodge; the effluents from his purification plant proper are turned into the overflow from it. The whole of the lodge is on his own premises. This overflow he passes down a culvert into another stream, of which the former is a tributary, so that it is impossible for us to take a sample at all of his effluents unless diluted perhaps thirty or forty times with this water from the lodge. We have no power of entry under the 1876 Act, therefore no means of obtaining a sample of his effluent proper. There are other cases I have in mind where water for condensation purposes alone, that is apart from the overflow stream, is also delivered into the effluent proper from purification plant.

823. Well, but is there any objection to that because you have got to deal with it as it leaves his premises. I suppose you might call dilution a kind of treatment?—I take it, that it is my duty to discover whether he has adopted the best known means in the treatment of his waste liquors, and to form any opinion upon that I must have a sample of the liquors after treatment by best known means, or see the plant he is using. In this particular case I can do neither.

Mr. W. Naylor, A.M.I.C.E., F.C.S.

13 July 1898.

824. But would you not say that the dilution was a form of treatment?—I should not care to advocate it as a form of treatment.

825. You would not deny that it was a form, would you?—In the case of sewage effluents it may be claimed with some reason that it is, at any rate that it assists in the later purification of the effluent, but in the case of the effluent of a paper mill or a bleach works I question whether the dilution would do much good.

826. You do not think the dilution would improve the effluent?—I question whether there is any such biological action going on in a bleach works effluent or paper mill effluent.

827. Then you would advocate the power of entry to premises and to take samples before any dilution takes place?—I would.

828. I do not understand your point 8. Sludging of mill dams or supply reservoirs; I am not quite sure what you mean by it?—Well, I should judge that Mr. Wilson has already given evidence on that point. I refer to mill dams or reservoirs, which contain the water to be used for manufacturing purposes or for any other purpose in a paper mill, or a cotton, or any other mill. We just had a case, two cases, where the owners of such lodges after drawing off the top water have conveyed or allowed to flow into a river the deposited sludge. That sludge, of course, had been deposited naturally from the river water.

829. The sludge is deposited in the reservoir or mill dam, and then what is it that is done?—The reservoir is fed by a stream or goit from a larger stream. The deposit of solids takes place in the lodge to such an extent that it becomes filled; in one of these cases it did become filled. Then the sluice of the lodge is opened, and the whole contents thrown bodily into the river. This is a solid solution, but not within the meaning of the Act so far as our cases have gone at present.

830. And all attempts at preventing that have failed, excepting at Common Law?—That is my experience.

831. And have they ever succeeded at Common Law?—I have the case in my mind of the Glory paper mill where a riparian owner below the mill did get damages, but it was at Common Law.

832. Then you consider that under the Act of 1876 the time, trouble, and expense incurred in obtaining penalties both for liquid sewage pollution and manufacturing liquid pollution is too great. It is questionable whether it does not pay both manufacturers and local authorities to wait for the first fine. In your opinion it would be an advantage if the Court had power to inflict a penalty, apart from orders to desist, six months after the service of notice of intention to proceed. That you state is your opinion?—That is my opinion, and I think under the present regime a manufacturer may always consider it safe that to go on polluting a stream for at least twelve months, indeed I have known cases of eighteen months and two years, after two months' notice of intention to proceed. We have first to get the permission of the Local Government Board, which rarely takes less than six months, then we have to get an order of the Court; the judge generally gives six to twelve months, and it is only after the expiration of that time that we can apply for the infliction of a penalty. Of course, under the Mersey and Irwell Act and the West Riding Act I believe the Local Government Board does give its assent or formally withhold its assent within a period of three months.

833. Then your last point is methods of treatment of sewage, and on that you say matters in suspension may be removed by simple subsidence, chemical precipitation, biological decomposition, either aerobic or anaerobic. Matters in solution (organic) may be removed by filtration through land, by artificial filters, filtration by mechanical filtration, or by biological decomposition. Combination of mechanical and biological. Trades' waste. Matters in suspension and fats in woollen wash waters by precipitation, and soluble sulphides in chemical works liquors by filtration through iron oxide, or precipitation by iron salts. Effluents from tanneries or breweries same treatment as sewage. I do not know whether you have formed any particular opinion as to whether you could obtain results as good from artificial filters as you can from natural filters by land?—There are cases in the Ribble Valley of good effluents being obtained from all and each of these processes named. I should not care to say really from which process we get the best effluent. There are several cases of good effluents proceeding from subsidence tanks only followed by land filtration, such is the case at Ormskirk, the Ormskirk Urban District Council's farm. Then there are cases of good effluents proceeding uniformly from treatment by precipitation followed by land filtration only, as is the case at Padiham and Clitheroe, again we have a case of precipitation followed by artificial filters and good results at Chorley. Although it must be added that effluents from artificial filters are more liable to vary than from treatment upon a considerable area of land. I think it varies really, because, as in the case of Chorley, the Polarite filters are liable to become choked, and must be left for some time to cleanse themselves. They are first mechanical and latterly biological filters. I have known such filters to become absolutely choked, and to refuse to pass tank effluent, and after being left for a week or a fortnight to take just about as much and with just as good results as when they were started in the first instance—the first day. I act also for the Somersetshire County Council, and have done so for some years, and in that county I have seen results of the biological treatment, that is the septic treatment at Yeovil, and there is no doubt in my mind but what the solids in suspension, the organic solids, can be liquefied, but a much larger area of filters must of course be provided than if precipitation had been resorted to in the first instance. There is one now being put down in the Ribble Valley, but I have had no experience of that. At Blackburn, for the past six months, experiments have been made on a fairly large scale with coke filters, preceded by a bacterial bed, on the lines suggested by Mr. Dibdin. At Burnley also, on a very large scale, filters have been laid down and used to the extent of over two acres, and I have no hesitation in saying that they are each and all capable of producing a satisfactory effluent, and were I empowered by any local authority to choose it would be largely on the matter of expense on the initial cost of the installation of filters that I should decide.

834. You have seen the Yeovil tank?—Yes, I reported on the Yeovil tank to the Rivers Pollution Committee of the Somersetshire County Council.

835. The Yeovil tank was put up by Mr. Cameron's process, was it not?—Yes.

836. But at Yeovil there is trade refuse as well as sewage?—The raw sewage from Yeovil is certainly the strongest that ever I met, because it contains a good deal of organic matter from the tanneries where they make gloves. These gloves are treated, as I was informed, by the yolks of eggs, which makes the sewage exceedingly strong. I examined a sample of the raw sewage, and it certainly was the strongest I ever met.

837. What did you find as to the effluent; did you find the effluent satisfactory?—Well, there was 80 per cent. purification effected, but that left an amount of organic matter which it has been my practice to object to in the Ribble Valley. I object in the Ribble Valley to any sample which yields albuminoid ammonia above ·2, and we have, in the county courts, obtained orders for effluents of about that character. In the case of Yeovil, if I remember rightly, the effluents contained ·3 and ·4 of albuminoid ammonia, and the oxygen absorbed was something like three or four whole parts per 100,000. Of course, a great deal more work had to be done on that sewage than on any sewage which is dealt with, at all events in the Ribble Valley.

838. You reported that the effluent was not, in your opinion, in a satisfactory state, I suppose?—I did.

839. And do you know what action the County Council took?—The County Council applied for an order in the County Court, and the Corporation of Yeovil submitted to the order, it having been agreed previously by both parties that it should be suspended for, I think, twelve months. That twelve months, to the best of my knowledge, has not yet expired; I have not yet been communicated with, at any rate.

840. They were going afterwards to try and make improvements?—Their proposal, as put to me by the borough surveyor, was to enlarge the filter area, in fact, only a portion of the sewage was under treatment at all, not the whole of it. It was intended by the Corporation to put the whole of the sewage under similar treatment, but to have the filters greater in proportion than they had been up to that time.

841. And the results of that are not known yet?—The additions are not yet completed.

842. Do you find, so far as the various processes of manufacturers are concerned that the dangers of pollution are increasing or decreasing?—It is my experience that they are decreasing.

843. Decreasing?—Yes, in certain processes of manufacture I find they are using less water than they did formerly, and they are abstracting the objectionable materials by dry processes rather than wet. That applies more particularly to paper-making. Moreover, they are discarding, as far as possible, dirty fibrous material and substituting wood pulp. In the case of bleach works they are using in many cases less in the way of material such as lime and soda. They have improved machines by means of which they can bleach or boil a given weight of cloth with less lime than formerly, and the same applies to the boiling with soda, a resort being made to higher pressure for lime boiling and soda boiling too.

844. Do you consider that the industries under your supervision have suffered in any way by the administration of the Rivers Pollution Act?—No, I do not; on the other hand, I think the disadvantages have been covered by the advantages, not always in the same mill certainly, but in the trade. I do not think that the trade on the whole has suffered. In some cases products have been recovered, for instance, the recovery of indigo in indigo dye works; in paper mills the loss of the wood pulp and fibre has been less, and in the woollen mills the fat has been recovered, at places that I can name, at a profit.

845. And speaking generally of the rivers in your district, do you think that in the past seven years there has been an improvement?—In the general condition of the rivers, yes. That is evidenced by the accumulations of sludge which have been extracted from the settling beds along the river banks.

846. (*Colonel Harding.*) I should like to ask Mr. Naylor whether he can give us a very brief summary of these reports in order that we may judge as to the number of pollutions with which the Joint Committee of the Ribble have to deal; whether he could tell us, for instance, how many local authorities his Committee have to deal with; how many cases of manufacturing pollutions they have to deal with?—Yes, I could; I could hand in a table.

847. If you will, refer us to it; is that one of the documents you have handed in?—This is a table which I had perhaps better detach showing the number of local authorities, drainage areas, authorities with and without interception schemes.

848. How many local authorities have you to deal with?—At the present time there are 42 local authorities.

849. Have all those local authorities methods of treatment of sewage?—There are six without sewage interception schemes at all; there are seven without sewage disposal works of any description; there are 31 with efficient disposal works and satisfactory effluents; of these twelve resort to precipitation and land, 13 to precipitation and artificial filters, six to broad irrigation or subsidence and land.

850. Now, as to manufacturing pollution, how many cases?—The number of manufacturers whose works are under the jurisdiction of the Committee is 65.

851. How many of those are connected with sewers?—I do not include any connected with sewers.

852. Those you leave out. How many treat their effluents, and how many do not treat?—There are 44 with efficient works of purification, and two without works of purification of any kind, and the difference, that is between the 46 and the 65, have only indifferent methods which we still complain of. Of the methods, there are 19 resorting to subsidence only, 20 resorting to precipitation only, and 22 resorting to precipitation and filtration or subsidence and filtration. The number using precipitants is 32, the number resorting to sludge pressing 4, the number reported as having been connected with the sewers since March, 1893, is 9.

853. Just one more question I should like to ask you, and that is, you have told us that you consider an effluent from sewage works to be unsatisfactory if it exceeds ·14 grains per gallon of albuminoid ammonia, have you not?—Yes.

854. Then what about the oxygen absorbed in four hours. You probably took that also into consideration?—I always in my reports put the two side by side.

855. What is the figure in your mind in regard to oxygen absorbed?—I have never been able to get any equivalent figure for oxygen absorbed, as we find the amount of oxygen absorbed varies very largely with the age of the sewage. I look upon the oxygen absorbed really as an index as to the condition with regard to putrefaction. A fresh sewage examined to-day will give less oxygen absorbed than the same sewage examined two days hence, so that if it happens that the sample has been standing in the bottle or standing in the tanks before passing through filters or over land, you really get more oxygen absorbed than should be the case, although there is no more putrid matter in it, but the organic matter in itself is in a more putrescent condition.

856. Then, do I understand that in judging of the quality of an effluent you leave out the question of the oxygen absorbed in four hours?—I do not leave out entirely the oxygen absorbed.

857. Do you judge entirely by the albuminoid ammonia?—I judge first by the albuminoid ammonia, and if that is above 0·2 I estimate the oxygen absorbed. If the oxygen absorbed were very low then I should hesitate before expressing an opinion without examining the nitrates or nitrites and chlorine (combined) in the sewage. At the same time I should want very strong evidence of nitrification having taken place before I considered that the sample had received satisfactory treatment which liberated so much albuminoid ammonia as 0·2.

858. At the same time, if it came from an artificial filter or from an irrigation bed and contained a large quantity of nitrites and nitrates, I should hesitate before I condemned it.

859. Then, in telling us that you consider effluents from certain sewage disposal works are satisfactory, you had in your mind that these effluents contain less than $\frac{2}{10}$ of albuminoid ammonia?—Yes, I did, and I have found that about 75 per cent. of the works in the Ribble Valley can easily manage to come under that 0·2, and where they do not it is evident to any one on going to the works that they are not resorting to the best means, that they are either cramped for precipitating space, or cramped for filtration area as compared with the other authorities where they do get below 0·2.

860. I think you told us that in Blackburn some experiments were being tried on a pretty considerable scale on the biological treatment of sewage?—Yes.

861. How long have they been working?—They have been working since January of this year.

862. You are unable to tell us as yet anything of the results?—Until within the last month I question whether the filters have really been got into what the promoters of the experiment would consider a right condition; but I can say this, that I have examined samples from those filters, and out of about eight, two only have come below this figure 0·2, the others being decidedly unsatisfactory—as high as 0·4, and 0·5, and 0·3.

863. And are they dealing in those beds with the effluent from precipitation?—At first they dealt with tank effluents from precipitation only, but latterly they were altered so as to receive crude sewage on the first bed, and that drains on to the second bed. The first is a coarse filter, a bacterial bed, and the second is a final filter. It is from the second filter that the samples were drawn, but they are not passing more than 80 gallons per hour for 24 hours—that is, the crude sewage.

864. (*Professor Foster.*) Is the second filter which has been adopted a mechanical filter?—No; the second filter is a biological filter, claimed to be used for dealing with the solids or the organic matter in solution only, and the first of the filters is essentially for dealing with the solid matter in suspension.

865. The two biological filters?—They are both biological filters, but if either of them is a mechanical filter also it is the first, because that does intercept the solids in suspension.

866. (*Colonel Harding.*) What becomes of those solids in suspension so intercepted?—I have seen them there, but I have not seen them taken away. It is claimed they do eventually become oxidised, or at any rate eaten up by the bacteria.

867. (*Professor Foster.*) That is another biological filter, then; they are all biological filters, then?—They are all biological filters.

868. (*Major-General Carey.*) They are divided into two, the coarse and the fine grain filter; the first is a rough filter, and the second a fine filter?—They are separate and distinct filters on two different levels. On the first is gas coke—I daresay which would pass through a two-inch ring, and the second filter is much finer, almost like granite chippings.

869. Are you able to give us any information as to the relative periods of rest or any detail to this Blackburn

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work, or must we obtain that from the Blackburn authorities?—I think the Blackburn authorities would be better able to give you that information, because knowing that they had officials regularly taking samples I have not done more than examine the samples as handed in by my sub-inspectors.

870. (*Dr. Russell.*) Do you work under the Rivers Pollution Acts in your Committee?—Yes, 1876.

871. You have no special Act as the other Committees have?—No; at the time that the Mersey and Irwell Committee was about to apply for their Act it was suggested by some members of the Committee—I think by the Clerk also—that we should also apply for a similar Act. However, the proposal was not acceptable to the whole Committee, and we decided to wait and see the result of the working of the Mersey and Irwell Act, and up to the present we have not seen that we are at much disadvantage.

872. You are aware that there is some difficulty with reference to the removal of sludge, and that there is a remedy in the local acts of the Mersey and Irwell Joint Committee?—As I understand it, the sludge difficulty is not removed, that the powers which the Mersey and Irwell Joint Committee have with regard to sludge refers only to sludge deposit in precipitation works, that is sludge which is the product of some manufacturing process, there there is a saving clause with regard to sludge deposited naturally by a river.

873. The matter was contained in Mr. Tatton's evidence, which states that the word "sludge" has been introduced referring to solid matters?—That is so, they can proceed with regard to sludging under that section of the Act dealing with solid pollution, for which there is a different law than for liquid pollution. If you wish to proceed, I think it is under Section 3 for liquid pollution, you are bound to get the permission of the Local Government Board; but if you are to proceed for solid pollution you can proceed without such permission. The words in the Mersey and Irwell Act and the words in the West Riding Act introduce the word "sludge" so as to bring sludge within the term solid pollution, but it does not refer to solid naturally deposited by a stream, at any rate there is a saving clause contrary to this.

874. Mr. Tatton says: "This is a term well known in "the North to express matter in a semi-liquid condition, "as found in a tank or reservoir in which water con- "taining suspended matter has been stored. It has "been a common practice to run off these reservoirs into "the stream, and eject accumulated sludge, causing seri- "ous pollution." Of course, it is a question of law, but it seemed to me that that met it?—I looked at the Mersey and Irwell Act in question, while we were proceeding with a case only a fortnight ago, the sludging case upon which we are now appealing, and I asked Mr. Tatton myself about it, his reply being that under their Act they could not proceed, because it had been deposited naturally; the West Riding Board have just lost an exactly similar case.

875. It is obviously a question of law. Then, as to the power of entry, it is quite specifically said that the power of entry has been granted for the purpose of taking samples with penalties for obstruction?—It has.

876. And all that goes as an argument for general legislation, so as to extend those amendments of the Rivers Pollution Act, which have been found necessary in such industrial centres as are represented by those Committees seems to be generally applicable?—I think it does.

877. Do you think that precipitation ought to precede a biological filtration?—That is a bacteriological question upon which I am not competent to give an opinion.

878. You seem to have more experience of bacteriological or biological filtration in your district than the other committees?—Including land, yes.

879. Blackburn and Yeovil?—Yeovil is in Somersetshire, and in the case of Blackburn, they, at the present time, are treating only a portion of their sewage by means of bacteriological filters, probably not more than $\frac{1}{10}$, the remaining $\frac{9}{10}$ is passed over a farm, a sewage farm.

880. It is only in the experimental stage?—That is so at Blackburn.

881. You have formed no opinion as to the power of those filters to deal with crude sewage?—No, I have not.

882. Are there any associations of trades such as we have in the north, such as paper makers, manufacturers and that sort of thing?—Yes, there is a Papermakers' Association.

883. Have they taken any combined action or expressed any combined opinion as trades with reference to any part of your procedure?—Yes, but that action at present has had no result.

884. Is it in your favour, or is it antagonistic?—It is decidedly antagonistic, and it has, I know been on the *tapis* at meetings that they should themselves promote a Bill in Parliament rather curtailing the powers of the Joint Committee.

885. So that they have not seen that your work has been to their advantage apparently?—Well, they do not admit that it is, and I should not care to say that we had come to the paper trade in any way as a benefit; neither do I think that was the object of the committee when it was formed. We were not received with a very great welcome, but I think they thought that we should really hit them much harder than we have done. In my opinion the cost to which they have been put in the paper trade does not amount to more per ton than the paper fluctuates in the market in the hands of financiers.

886. Other witnesses have told us that the paper manufacturers had really benefited by your restrictions of their output of solid matter and soda?—I should not care to say that the paper makers have really benefited on the whole.

887. Especially in view of the fact that they use wood pulp so largely now?—Wood pulp I do not think has been long in the market to the extent it is now. The mills I know I think would have resorted eventually to wood pulp had these three Committees not come into existence at all.

888. So that you will not recognise the material benefits to the manufacturer in that instance, at any rate?—I should not care to go further than this: to say that they have not been so hardly hit as it was generally anticipated they would. To say that they have received much advantage, I think is going too far, because, to begin with, a good many of them—I daresay most of them—have had to resort to pumping liquors before treatment to a considerable height, which of course is, in the case of half a million gallons a day, a very considerable expense. I do not think the paper traders themselves would say they had been benefited; in fact, the formation of this combination of the paper trade rather points the other way.

889. Of course all that is in addition to the cost of production; have you recognised any element in their antagonism arising from this; that these restrictions are not applicable to the whole land, and that they are in an invidious sort of opposition to their own interests as competitors?—That is an argument that I have often heard put, that paper-makers near the seaboard are not in this way handicapped, and they look upon it as rather unfair, and often they advocate the administration of the Act in exactly the same way throughout the whole of England and Scotland for that matter.

890. Do you think that is quite a reasonable view?—I do indeed. Those complaints have been made to me both in Lancashire and by the paper-makers in Somersetshire.

891. (*Professor Foster.*) Do I gather, Mr. Naylor, that you are not wholly satisfied with the tests for the purity of the effluent; the tests you have employed?—No, sir; that is not what I meant to convey.

892. Have you not pointed out, I mean, that the oxygen absorption test is one which must be employed with care?—That is so, but it is not the test upon which I really rely. From the very beginning, in 1892, I used the albuminoid ammonia test. Various members of my Committee are—well, more than half of them—members of the Lancashire County Council, and as in that capacity they receive the reports of the Mersey and Irwell Committee, also, they thought it strange to see one Committee's results in the oxygen absorbed and the others albuminoid ammonia. The Ribble Committee's figures were expressed in albuminoid ammonia, the Mersey and Irwell Committee's figures on the oxygen absorbed, and when the matter was brought before the notice of the Committee I undertook to present also a second column of oxygen absorbed. Then, to my dismay, I found that, placed as they are always in order of amounts, that particular sample with the lowest amount of albuminoid ammonia at the top, and that with the most at the bottom, the figures for albuminoid ammonia did not coincide with the oxygen absorbed figures, and to get out of that difficulty I resorted to a different test of oxygen absorbed. I boiled for two hours. Then they certainly did tally to a greater extent. It was then the highest for albuminoid ammonia—the highest for oxygen absorbed—and vice versâ, but the figures for oxygen absorbed were so exceedingly high that they did not serve the purpose for

which they were intended, namely, a comparison between the Ribble, Mersey, and Irwell results.

893. You mean by the process of boiling you had increased the oxygen absorbed?—Exactly. At the same time it made the ratio between the two more permanent, then I went back, and have followed for the last three or four years a four hours' test at temperature of 80 deg. Fahrenheit; but if I do not estimate the oxygen absorbed at all in as much as the albuminoid ammonia amounts to less than ·12, and by leaving out all those figures below ·12 of oxygen absorbed, I managed to get the bottom half of the figures more nearly alike; that is, you are more likely to get a constant ratio between albuminoid ammonia and oxygen absorbed if there is a greater quantity than if there is a small quantity.

894. May I gather then that you do not place great trust in the oxygen absorbed test?—I do not. I only regard it as a relative test for determining the putrescence of the sample, the age of the sample. I know for a fact that a fresh sample will absorb more oxygen two days later than it does when it is first drawn.

895. That is to say, during those two days a certain change has taken place in the organic material?—I take it that decomposition has set in, the compounds have become less stable, and, therefore, in a condition to absorb more oxygen than they were previously.

896. And that decomposition is brought about by——?—I should say it is biological decomposition.

897. By organisms?—I should say so as a chemist.

898. You have never examined that point at all?—I do not speak at all as a bacteriologist; I am ignorant on the matter.

899. And that decomposition; the rate of that might vary under different circumstances, might it not?—Undoubtedly.

900. So that I mean you take two samples of sewage, both of them having the same very slight absorption of oxygen, or even absence of absorption of oxygen, and after two days' rest, while you were examining them under the same conditions, one might have a very great increase, and the other a relatively small increase in the oxygen?—I quite see the possibility of that.

901. (*Professor Ramsay*). Might I ask you, Mr. Naylor, what you mean precisely by absorption of oxygen? Do you refer to the amount of permanganate used, or the amount of free oxygen taken up?—I mean the oxygen absorbed as determined from the amount of permanganate decomposed.

902. Are you aware that experiments have been made on the absorption of free oxygen, atmospheric oxygen?—I have seen in the scientific papers and journals mention of the matter, but I have not followed it closely. I believe at Dublin there were some experiments made.

903. You have not yourself made experiments of that kind?—No, I have not.

904. Do you know whether experiments have been made in connection with either of your Boards?—I have not heard of any in connection with the Mersey and Irwell Board, and I know that no such experiments have been made with regard to my own Committee.

905. Do the two tests, the permanganate and the albuminoid ammonia, not run very much *pari passu*, because the method of estimating albuminoid ammonia is distillation with permanganate, is it not?—Yes.

906. Would you not imagine that, if the albuminoid ammonia were great in amount, the amount of permanganate destroyed would also be great in amount?—Yes, but there is always a very great excess of permanganate.

907. But the amount destroyed would be in proportion?—The amount destroyed is bound to be much greater if there is a greater amount of organic matter present. Of course, it is done by a boiling temperature in the one case, and in the other case at 80 degrees Fahrenheit.

908. Then is that the reason that you adopt the process of boiling?—Undoubtedly, that was a method that occurred to my mind likely to result in the two coming out about the same.

909. And you find that that is so, more or less?—I find there is a decided relative proportion in low and in high amounts by boiling. At the same time, the figures, as compared with the four hours at 80 degrees Fahrenheit, were more than quadrupled, so that my best sample would probably have a higher figure for oxygen absorbed than the Mersey and Irwell's worst done at the four hours, which made matters really worse than before.

910. I suppose you regard it as quite obvious that other carbon compounds besides those, capable of yielding albuminoid ammonia, might be acted upon by permanganate?—Undoubtedly. I look upon that as rather an objection to oxygen absorbed. I find that effluents which are low in albuminoid ammonia are always much higher when those particular effluents have come from irrigation areas. I find that invariably so, and I have often drawn attention to it, that a sample, say, liberating albuminoid ammonia ·1 would have oxygen absorbed possibly ·6 from an irrigation area, but only 0·3 from an artificial filter, which I think is really due to other carbon compounds, which you have suggested, having been picked up in irrigation areas.

911. Have you made any experiments with peaty waters in that respect?—No, but we have one or two farms which are of a peaty character, and this is more notable in those cases than in any others.

912. (*Professor Foster.*) When you are dealing with your permanganate to get your test for albuminoid ammonia, you are really, are you not, oxidising albuminous matters?—Yes, precisely.

913. But in your simple boiling, previous to the application of your permanganate, you are simply, by some means or other, bringing those albuminous matters into a less stable condition?—No, sir; I think you misunderstand. The boiling does not take place before the permanganate is added in the oxygen absorbed boiling; the boiling takes place in the presence of the permanganate.

914. I thought it was boiling first, and then adding the permanganate afterwards?—That is not so. It is boiled in the presence of the permanganate, and the two processes are identical, except that one is alkalin and the other acid.

915. (*Professor Ramsay.*) That is always as regards the reduction of permanganate present; you add much more in the one case than in the other?—Much more.

916. Have you resolved upon any standards which you would like to see introduced?—Well, I know I am treading on very debatable ground; and that standards generally are not received with much *éclat*, but I must confess that I have seen no reasonable objection to a standard, and I think it would have many advantages. I think, for instance, all manufacturers, no matter how they are situated, can reduce the matter in suspension below, say, three parts per 100,000.

917. May I interrupt you at this stage, and ask you: Do you agree with Mr. Scudder that, by reducing the suspended matter, you concurrently reduce the amount of dissolved matter?—Not necessarily; I do not see how that should follow, unless precipitants are used in the reduction of the suspended matter, which precipitants might throw down the matter in solution. Of course, everything depends upon what the matter in solution is.

918. Precisely, yes?—But with regard to suspended matter, I know a good many cases where it is removed by simple subsidence, in which case the matter in solution is.

919. (*Professor Foster.*) But are there not many instances of matters in solution which are carried down by the precipitation of substances in them?—Well, of course, there is always free lime in paper mills effluents, and that might be carried down by the addition of metal—by an iron or alumina salt.

920. I mean organic matter, such, for instance, as albuminous matters, which you would say are in a state of solution if you were producing them—a precipitation of material then, by adding foreign material, and it is found that the quantity of albuminous matters in solution has been diminished, that is to say, carried in some way mechanically down by the precipitant without being themselves actually precipitated?—Yes, I am quite aware that in the case of sewage particularly, organic matter exists in a sort of colloidal state, which is neither in solution nor suspension, and that aluminium hydrates or aluminium oxides have the power of carrying it down. I have often been compelled to give that matter attention in getting up evidence for cases in the Court, but I never found that it amounted to a very great deal. I have known that that point was to be introduced by witnesses acting for the local authorities against which we have been proceeding, and, knowing that, some weeks before I have

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made experiments with the idea of finding out to what extent organic matters in solution can be precipitated, and I have always been compelled to state in the witness-box that it does not amount to a very great deal; at any rate, certainly it has not been sufficient to dispense with further treatment. Precipitation cannot be relied upon alone.

921. (*Professor Ramsay.*) Would you regard it in any way as a preliminary stage; I mean to say this: It might be unjust at first to force manufacturers to purify their water by undertaking chemical precipitation. Would you regard it as a preliminary stage, an advisable preliminary stage, to make them purify their water by subsidence or by simple filtration, so as to remove suspended matters?—I should not lay down any particular rule which they were to follow for the abstraction of matter in suspension. I know cases where they get it nearly all eliminated by means of subsidence only, where no precipitants are used. I know other cases where it will not settle. I know cases where the lighter matter in paper mills will not fall at a greater rate than one foot in six hours, whereas if a precipitant is added, as copperas, it will fall at the rate of two feet per hour. In fact, my experience is that the precipitate of copperas and lime at the rate of 10 grains, say, of lime and five of copperas, will fall at the rate of two feet per hour. In cases where the rate of deposit is so slow as one foot in six hours, it might pay a manufacturer to use precipitants, especially if he is cramped for settling space, but if he is not cramped he may prefer to have a larger tank, and do away with the precipitants altogether.

922. Then, to come back to the point we started with. Would you make it necessary for the manufacturer to reduce the suspended matter to some definite maximum amount?—I would, and I know of no mill, whether it be in town or in country, that could not conform to that rule.

923. Then, as regards further purification, have you any idea as to standards for sewage contamination?—Well, of course I can only suggest in that the standard that we are working upon unofficially. It is well known to the Committee, and in the Ribble Watershed, that is, I made a complaint if the effluent is not brought below 0·2 albuminoid ammonia, subject to nothing special being divulged. But under special circumstances we resort to an examination for oxygen and nitrates. I should not agree to make any hard and fast standard for the oxygen absorbed, because I think everything depends upon the age of the sample.

924. Then are there any other standards which you would suggest as regards the presence of foreign metals—I mean, bearing out the lines of the Report of the Commission of 1868?—I think initially I should not do more than that with regard to sewage, nor more than the matter in suspension with regard to manufacturers, unless to prohibit anything like an alkalinity or acidity which is perceptible by litmus.

925. What does it mean numerically; what amount would you say?—I mean to say that practically it can be neutralised, so that litmus is not affected appreciably.

926. But you do not know how much acid that requires?—No; it is certainly rather vague; I am speaking only generally. A good deal would depend on the litmus. I would state generally it should be neither alkaline nor acid; but neutral.

927. Then also there were some other recommendations I think as regards colour. I think you would say that the water should not be deeply coloured at all events?—I should not agree, sir, to make any objection to the colour.

928. (*Major-General Carey.*) The tests of impurity in the Ribble watershed and the Mersey and Irwell are essentially different, are they not; you cannot readily compare the two?—They cannot readily be compared; neither to the best of my knowledge can any other two tests. I did use Sir Edward Frankland's test before Mr. Scudder or Sir Henry Roscoe acted for the Mersey and Irwell Committee. I was engaged by them in the action against the Bury Corporation. In that case I used the organic carbon and nitrogen test propounded by Sir Edward Frankland. It was objected to by the chemists engaged on the other side as being uncommon, and with the idea of getting a ratio between that and albuminoid ammonia certain experiments were carried out by me and Mr. Davies, the editor of the *Chemical Trade Journal*. But we came to no satisfactory conclusion at all. We could not get a ratio between the two, neither do I think it is possible. I know it has often been tried to get a ratio between the oxygen absorbed and the albuminoid ammonia, and the organic carbon and nitrogen.

929. Your ·2 albuminoid ammonia, as far as I understand, is as nearly as possible equivalent to the ·3 of the Royal Commission of 1868, ·3 of organic matter?—I think it is. Of course, you get less of the albuminoid ammonia rather; the actual nitrogen in ·2 will be fourteen-seventeenths of ·2, a little less, but that I believe is about the equivalent of ·3 that the first Rivers Pollution Commission suggested.

930. Then have you prepared any details of your results of the different methods of treatment that the Mersey and Irwell Joint Committee have given us?—I have not any detailed statement, but I am quite prepared to say that we have had good effluents, that is, we have had albuminoid ammonia below ·1, we have had ·08 and ·09 from every process of treatment in the watershed. Of course, none of them is permanent. You may go one day to an artificial filter and get an exceedingly good result; another day probably from some causes that are uncontrollable you will not get such a good result. The same thing applies to land, perhaps not due to the same causes; it may be due to flooding, or the land may have become saturated. I think I ought to say at this point that when it was reported to my Committee on Monday that I should attend before this Commission several members of the Committee expressly wished me to point out—said so publicly—that most of the land being used for sewage farming is of a nature hard and clayey, and not suitable in its present condition for filtration purposes.

931. And they have not attempted to purify the sewage through this unsuitable land. Are those the cases in which artificial filtration has been adopted?—Well, in most of the cases they have resorted to artificial filtration because of the nature of the land; with the land they had they were unable to produce an effluent that was satisfactory. Blackburn is a case in point. They are resorting now to artificial filters, because they claim, rightly or wrongly, to be unable to produce an effluent of a satisfactory character from the land they have got. The Borough of Accrington—it is not a case in point, they have no land at all there—are resorting to artificial filtration; they claim, rightly or wrongly, that there is no land in the immediate neighbourhood that is suitable for sewage treatment. I know of my own knowledge that the land in the immediate neighbourhood is of a clayey character.

932. (*Sir Richard Thorne.*) May I take it from your answer to General Carey that you are not in a position to give us any comparison in the Ribble Valley between precipitation with artificial filtration and precipitation with land filtration?—I should say it is impossible now or at any other time to draw a comparison between artificial filtration and land filtration unless the results on which that comparison were made extended over twelve months at the very least. It is a common thing to find the effluent good at one portion of the day from a sewage farm and not so good at another. The same thing applies exactly to artificial filters. I have had a sample of the Blackburn artificial filters giving 0·07; and a sample giving 0·4 and 0·5 the same week.

933. But does this mean that you have not had sufficient time in the Ribble Valley to form an opinion?—With regard to biological artificial filters yes, but with regard to mechanical filters or such as the polarite filters I say no. We have had quite sufficient experience with these to form an opinion.

934. Take biological filters, can you compare those with land, that is to say, precipitation preceding in each case the filtration?—I do not think anybody can.

935. You cannot?—I cannot.

936. Have you any experience as to the effect of trade effluents on the action which is desired to be achieved by means of septic tanks?—No, I have not.

937. (*Chairman.*) Would you not say your Yeovil experience was?—Well that, my lord, is trade refuse, differing very little indeed from the sewage in the sewers into which it enters. That is trade refuse of an absolutely organic character. I had in mind when the question was asked the case of Wolverhampton. I was formerly with the Wolverhampton Corporation, and I had in mind the galvanisers' pickle. Well, speaking as a chemist, not as a bacteriologist, I should suggest that the galvanisers' pickle would have rather a deleterious effect on any biological system of sewage treatment. Of course, the same

thing applies in the case of St. Helens, in Lancashire; there is a good deal of galvanisers' pickle entering the sewers there.

938. (*Professor Ramsay.*) Would you explain what galvanisers' pickle is, Mr. Naylor?—With pleasure. In the case of Wolverhampton the staple industry is the making of corrugated iron sheets, which are coated with zinc. The sheets are passed through molten zinc; before passing through they are allowed to stand in sulphuric acid, so that any oxide on the surface will be dissolved, and that the plate as passing through the molten zinc will present a surface of pure iron, to which the zinc will adhere. Then the acid in which the sheets have been standing is known as galvanisers' pickle. It is sulphate of iron. In the case of hydrochloric acid being used it is muriate of iron. But why I say it would probably be prejudicial to any biological treatment is that the acid is very rarely neutralised before it is thrown away. It is always in my experience acid at the time it is thrown away. The process would be so slow that it would not pay to keep it towards the end. They would get new acid rather than allow the slow process to go on.

939. (*Sir Richard Thorne.*) There was one answer of yours which I did not quite follow. If I understood you rightly your opinion is that it would be fair to require as regards a trade effluent passing into the sea as high a standard as that which had to flow into a watercourse, which might be used for various purposes below; did I understand you rightly?—No, sir, I do not think you did; well, you do not now understand me rightly because I was not aware that I made that statement. When I speak of standards I am referring only to factories and authorities under the Rivers Pollution Act.

940. Pardon me, I do not mean "standard" from the chemical point of view, but that the effluent which goes into the sea should be as pure as is required of manufacturers who have not the advantage of the sea and are obliged to pass their effluents into watercourses. I think you said a claim had been made by manufacturers that all should be treated alike, and you thought it was only fair they should?—No, you misunderstood me. I have badly expressed myself. What I meant was this, that manufacturers inland complain that the trade is being driven to the seaboard, that manufacturers go there, and further that they are not treated in Lancashire, and in Somersetshire and in Yorkshire as they are in Leicestershire or Nottinghamshire, or at a seaboard. Of course, the Act is not in operation in some countries, and it is not in operation at the seaboard; that is what I mean.

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941. No, but to whose advantage would it be that a person delivering his effluent into the sea where it could do no harm should be treated with the same severity as a manufacturer in the Midlands passing his effluent into the stream where it would do harm?—I should not for a moment propose to treat a manufacturer on the seaboard or in a tidal estuary in the same way as a manufacturer on the upper reaches of the river.

942. Then there must be inequalities as regards the cost of production from that point of view?—Undoubtedly there is. I am afraid I have not been clear on the point yet. A manufacturer in Lancashire, I should have said, complains that he is being treated more roughly than a manufacturer at the seaboard, or a manufacturer who is not at the seaboard, say, in Leicestershire, if there should be a paper mill there where the Act is not really administered.

943-960. (*Chairman.*) There is only one more question I should like to ask you. You deal, I presume, with a large quantity of land. I mean, your experience of sewage treatment is over a great deal of land?—Yes.

961. And you have told us that a great part of that land is clay?—Some portion of it is clay; I should not care to say the greater portion is clay; I said that I knew instances where there was land of a clayey kind; I should not care to say more than that.

962. And are you of opinion that the clay land is very unsuitable for sewage treatment?—Yes, I am, unless it is specially treated.

963. And, also, I gather from your evidence that you find the result on the sewage produced by land treatment varies very much?—It does.

964. It varies more than you would have expected probably?—I said the effluents varied. Of course, varying effluents may be due to other causes than the direct effect of the land; they may be due to ground water, or to rain in the case of land, but are not so likely to be due to the same causes as in the case of artificial filters.

965-970. Of course effluents are exposed to more accident in that way, but practically you do find that an effluent, which is treated only by land, varies much in its quality?—It does.

FOURTH DAY.

Thursday, 14*th July*, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary*.

Mr. TREVOR EDWARDS, called; and Examined.

Mr. T. Edwards. 14 July 1898.

977-979. (*Chairman.*) You are Clerk and Solicitor to the West Riding of Yorkshire Rivers Board?—Yes.

980. What is the constitution of the West Riding of Yorkshire Rivers Board?—The West Riding of Yorkshire Rivers Board was formed under the title of the Joint Committee for the Rivers of the West Riding of Yorkshire by a Provisional Order of the Local Government Board, made under Section 14 (3) of the Local Government Act, 1888, and confirmed by the Local Government Board's Provisional Orders Confirmation (No. 16) Act, 1893. Its present title was given by its Special Act of 1894. The Board consists of thirty members elected by the Councils of the Administrative County of the West Riding, and the five County Boroughs of Bradford, Halifax, Huddersfield, Leeds, and Sheffield, from among their members, as follows:—By the Council of the County of the West Riding of Yorkshire, eighteen members; by the Council of the County Borough of Bradford, three members; by the Council of the County Borough of Halifax, one member; by the Council of the County Borough of Huddersfield, one member; by the Council of the County Borough of Leeds, four members; by the Council of the County Borough of Sheffield, three members. The constituent authorities contribute towards the expenses of the Board in the proportion of the number of members elected by each, and this may generally be taken as representing their rateable value in proportion to the rateable value of the geographical county.

981. What is the area of the Board's operations?—

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The area of the Board's operations extends to the geographical county of the West Riding, which embraces the rivers Ouse, Ure, Nidd, Wharfe, Aire, Calder, Don, and Trent, all falling into the Humber; the rivers Tame and Ribble flowing into Lancashire; and the river Lune flowing into Westmoreland. The sanitary districts within that area are 170 in number, consisting of:—Five County Boroughs, thirteen Non-County Boroughs, 122 Urban Districts, thirty Rural Districts; total, 170.

982. What is the acreage, population, and rateable value of the Board's area?—The acreage, population, and rateable value of the geographical Riding are as follows:—

	Acres.	Population, Census 1891.	Rateable Value.
			£
The Administrative County of the West Riding of Yorkshire - -	1,701,877	1,351,672	7,157,022
The County of the City of Leeds -	21,572	367,506	1,518,651
The County of the City of Sheffield	19,651	324,243	1,274,000
The County of the City of Bradford - - - - - - -	10,776	216,361	1,130,375
The County Borough of Huddersfield - - - - - - -	11,788	95,420	437,313
The County Borough of Halifax -	8,209	89,833	373,857
TOTAL, RIVERS COUNTY - -	1,773,873	2,445,035	11,891,218

983. What were the reasons of the Board's establishment?—The chief reasons for the creation of the Board were:—First. The exceedingly foul state of the rivers of the Riding threading the populous districts, and the general abuse of all the rivers by their being made the scavenging agency for the solid and liquid filth of the towns and villages. Second. The non-exercise by the sanitary authorities of their powers under the Public Health Acts and the Rivers Pollution Prevention Acts, for the preservation of the natural condition of the rivers and streams. Third. An increasing public opinion in favour of purer and more sanitary waterways.

984. What are the powers of the Board?—The powers of the Board are generally:—First. Those of a sanitary authority under the Rivers Pollution Prevention Acts. Second. Those under their own Special Act—the West Riding of Yorkshire Rivers Act, 1894.

985. In what respect does the Special Act of 1894 differ from the general Acts?—The main differences between the general Acts and the Board's own Act are:—(1). The County Court is the tribunal for trying offences under the general Act, while under the West Riding Act, 1894, it is that of the Magistrates. (2). The Act of 1876 requires a two months' notice of action in all cases before legal proceedings can be instituted, while under the Act of 1894, no prior notice is required except to manufacturers in respect of liquid manufacturing pollutions, in which cases a special procedure of preliminary investigation must be observed. (3.) The Act of 1876 requires proof of pollution or obstruction in respect of solid matters thrown into the rivers, while the Act of 1894 makes the casting in of extraneous solids an offence, irrespective of consequences. (4). The Rivers Board and the Local Government Board are made the arbiters of the feasibility and reasonableness of cost of purifying trade liquids in lieu of the Court or a Local Government Board Inspector, as under the Act of 1876. (5). A power of entry for the taking of samples of effluents is given under the Act of 1894, while none exists under the Act of 1876. (6). The Act of 1894 requires the use of efficient settling tanks before the discharge of coal washing effluents into a stream. (7). The Act of 1894 defines "liquid sewage" for the first time in legislation.

986. What was the reason for obtaining the Special Act?—The reason for obtaining the Special Act of 1894 was mainly to obtain a more expeditious procedure, so as to assimilate the prevention of nuisances to rivers to that of nuisances under the Public Health Acts.

987. What is the average cost of the administration of the Rivers Board?—The present normal expenditure of the Board is about £6,000 per annum, or about 1-7th of a 1d. in the £ upon the rateable value of the Riding.

988. Of what does the establishment of the Board consist?—The staff of the Board numbers seventeen persons, consisting of one clerk and solicitor, one chief inspector, six clerks, and nine district and assistant inspectors.

989-991. Has the Board encountered any difficulties in prosecuting its work?—The chief obstacles in the path of the Board are:—(1). The reluctance of sanitary authorities to expend money on works of sewage disposal, owing to the non-productiveness (as it is erroneously termed), coupled undoubtedly with the fact that efficient sewage purification as at present followed, is costly. (2). Similar reluctance by manufacturers on the ground of diminution of profits. (3). Indisposition of sanitary authorities to receive trade liquids on the ground mainly of the enhanced cost of treatment of an enlarged volume of sewage; and the dissatisfaction of manufacturers at the refusal by sanitary authorities in many districts to receive trade liquids, coupled again with the costliness of purification. (4). The still lingering belief born of long usage that the flowing streams are the natural means for carrying away the offscourings of the population.

Dr. H. MACLEAN WILSON, M.D., B.Sc., Chief Inspector of the West Riding of Yorkshire Rivers Board, called; and Examined.

Dr. H. M. Wilson, M.D., B.Sc.

992. You are Chief Inspector of the West Riding of Yorkshire Rivers Board. How long have you held your post?—Since October, 1896—one year and nine months. I succeeded Dr. Whitelegge, who was also the County Medical Officer.

993. What are your duties under the Board?—I have the supervision of the outdoor staff of the Board, nine inspectors, each of them having a district allotted to him, and I have also the chemical work in charge of the laboratory belonging to the Board, which has now been established some ten months, and have generally to advise the Board in all cases of proceedings.

994. Is your whole time given up to the service of the Board?—My whole time is given up to the service of the Board.

995. You do no other work?—I do no other work.

Appendix No. 12.

996. Could you give us any description of the rivers coming within the jurisdiction of the Rivers Board?—I think, my Lord, if you will look at this map which I sent in you will see the river valleys. With the exception of *this* small part and *this* (*indicating*) all the county slopes towards the east to the Humber, and these are the river valleys. In this map the rivers themselves are marked. *These*, the Ure, the Nidd, and the Wharfe, and the Ouse and the Trent tributaries are practically clean streams. There is very little pollution in these streams; the Aire, the Calder, and the Don are most polluted. The Aire down to Bradford is practically a clear stream, it is not much polluted; from there down to the Ouse, where it joins the Ouse, it is really an open sewer. It conveys a great part of the sewage of the county borough of Bradford, and the partially purified sewage of Leeds. The Calder rises at Todmorden just on the border of Lancashire, and from Todmorden it is polluted the whole way down by the sewage of Todmorden Borough, and the other places down here, and the county boroughs of Huddersfield and of Halifax drain into it. The Don is polluted not with sewage or ordinary trade effluent, but with ochre water from the mines at the top part down as far as Sheffield. The sewage of Sheffield is only partially purified, and there are several places below with unpurified sewage going in, so that the state of the river below is very bad, though not so bad as the Aire and Calder. This small tributary of the Mersey, the Tame, is very much polluted with trade effluents; there are about forty woollen and other mills on the stream.

997. How should you say the state of the rivers at present compares with their state when they were visited by the Royal Commission in 1865?—Well, I should say that probably they are quite as bad now as they were then (although a great deal of improvement has taken place lately for several reasons). The population has been increasing greatly, and public water supplies have been put in instead of supplies from wells, and a great number of dry closets and privies have been converted to water closets. Sewerage schemes have been carried out, so that a great deal of refuse which formerly did not reach the streams does now reach the streams, and the construction of purification works has not been keeping pace with that.

998. Are the waters of the streams impounded in many

cases for water supplies?—I have submitted another plan of the Calder basin, which shows pretty well the state of matters on most of the rivers. Those areas coloured blue and yellow round the fringe of the Calder basin round the watershed are gathering grounds that have been taken up, and you will be able to see that practically all the upper reaches of the stream have been impounded for water supplies, and the same is true of the Don, and to a great extent of the Aire, and partly of the Wharfe as well.

999. Do you put in a report of the pollutions by domestic sewage?—That is, my Lord, the large report of the survey of the whole Riding which was made by the Rivers Board, so that they might see the outfalls of domestic sewage and the sewage works within the Riding.

1000. Is this the report (*exhibiting volume*)?—The smaller one of those two volumes, that deals with domestic sewage.

1001. Yes, I see. When was this made?—This was completed in 1896, and in it there is a good deal of the work which was done at the instance of the Board, following on the work done by the County Council previous to the constitution of the Board.

1002. Do you present these copies? We may keep these?—Yes.

1003. Have you any remarks that you wish particularly to make on the subject?—As to the extent of the work there are five county boroughs in the jurisdiction of the Board, 13 non-county boroughs, and 122 other urban districts, and 30 rural districts. Then the progress made since the report was presented in 1896 is marked in red ink in those copies which have been handed in, but in addition to that—those red ink marks only refer to actual work done—in addition to the actual work done a very great deal has been done in rousing the sanitary authorities in the Riding, and drawing their attention to the pollution of the streams, and I would refer to the next table—tables D—in the statement, which show the pollutions by sewage on the individual rivers, and a statement whether there are sewage works or not, and as to the position of the authorities, whether they have works in progress or schemes before the Local Government Board or plans in preparation. By looking at the column of remarks, I think you will see that a very great deal is in contemplation and in progress in the Riding.

1004. Yes. Now we come to the question of the nature of the land available. Do you agree with what we were told yesterday that clay land is almost useless for the purpose?—Certainly, my Lord.

1005. And do you say that both about clay land in grass, and therefore the surface of which is not disturbed, and also about arable clay, which is broken up and ploughed every year?—Certainly. I think stiff clay land such as we meet with frequently in the West Riding is useless for sewage disposal.

1006. You do, whether arable or whether grass?—I do. I should like to draw your attention to two or three instances in the Riding. There is a large sewage farm of 80 acres provided for Eccleshill Urban District, and sanctioned by the Local Government Board in 1878. The sewage was supposed to be applied to the land by broad irrigation, but after an attempt to use it the land was found to be practically useless for purification purposes, and for many years its use was given up. The Rivers Board insisted that the land should be used pending some improvement being made in the works. An improved scheme is being adopted, but the sewage is now running on to the land and running off again with very little purification beyond the settlement of some of the solids. Then there are recent cases. There is a case of works in progress at this present time at Hebden Bridge, where the land is exceedingly stiff clay, with a mere sprinkling of humus upon the top, and there obviously the sewage will be quite unable to percolate through the soil. There is some preparation of the soil by draining, and the trenches for the drains have been filled up with coke, but obviously the only escape for the sewage will be through those trenches of coke, and the rest of the land where the subsoil, the clay, has been undisturbed will be practically useless. Then sometimes this kind of soil is dug up and burnt and replaced, and this has lately been done at Ossett, where they had a stiff clay land for their sewage treatment; about 10 or 12 acres were dug up for something like 3 feet deep; the clay was burnt and replaced. It works somewhat more satisfactorily now, but not satisfactorily yet.

1007. Have you any idea of the sort of number of acres of land in your district that would be used for sewage farming?—In proportion to the—

1008. No; I mean, have you a wide experience; is there a great deal of land used?—Oh yes. I have not summed up the total; I could easily have that summed up for you.

1009. Would it amount to a thousand acres or more?—Oh, many more than that.

1010. Many more than that?—Many farms up to 80 or 100 acres.

1011. I mean, you have the experience on a big scale?—There are some 230 sewage works of one kind or another in the Riding, and probably more than one half of those have land.

1012. Then your experience is extensive?—Oh, yes.

1013. Now, do you agree with what was told us yesterday, that the results of land filtration are very uncertain, that you find a good effluent at one time and a bad one at another?—I think not, my Lord, granted that the land is good and plentiful. The results are very uncertain on different farms owing to the nature of the soil, and very often to the nature of the sewage treated. But given a farm with good soil and plenty of it, so that the sewage can be changed from one part of it on to the other as necessary, then I think the results are usually pretty much the same. It is a matter of management.

1014. I have heard it said that comparing land filtration with artificial filtration the best land filtration is better than the best artificial filtration, but that the average of artificial filtration is quite equal to the average of land filtration. I mean that if you take the actual samples that you would get that would be the result that would be found. Of course, you cannot answer whether that is so or not, but should you be disposed to think that, or should you be disposed to think that the average of land filtration was better than the average of artificial?—I think that the average of land filtration as in the Riding is better than the average of artificial filtration.

1015 You think it is?—Because, probably, mismanagement of the land does not lead so rapidly to bad results as mismanagement of the artificial filters.

1016. But, of course, an artificial filter can be very much more easily managed than the land?—Well, no, my Lord; I think probably the land is easier to manage, and at any rate it does not so soon show the results of mismanagement. If there is mismanagement it spoils the land; there is a silting up of the upper layers of the soil, but that land will soon recover itself; if the sewage is turned off from that portion on to another the mismanaged portion will recover soon. In the case of the filters, the sewage when the filters are mismanaged continues generally to pass through the filters unless they are composed of very fine material, very fine sand, when they silt up; but supposing they are composed of coke breeze or burnt ballast, or anything of a coarser material, the sewage passes through, but is not purified in its passing through. In the case of land the land silts up, and does not let the sewage through.

1017. Do you consider that the land will go on for ever cleansing the sewage without suffering itself, provided, of course, you alternate it?—If it is turned over and cultivated and properly managed it ought to.

1018. To go on for ever?—Yes.

1019. You do not consider there is any injury to health from the fact that there is so much of the land in the neighbourhood absorbing sewage?—I should not like to say that definitely; there are many of the sewage works in the Riding I think far too close to populous neighbourhoods, and although I could not point to any definite injury to health I would be strongly of opinion that having mismanaged sewage farms near populous neighbourhoods was injurious.

1020. You would?—Yes, not that it produces any definite disease, but a general deterioration of health.

1021. I have always myself a horror of seeing milch cows feeding on grass land which is part of a sewage farm; has that point ever been raised in your mind?—Yes; I have often thought it was quite a wrong proceeding to have dairy cows on a sewage farm, but I think the only case in which my attention has been drawn to it in the Riding is in the rural district part of Kiveton Park Rural, where the farmer who had cows on the sewage farm said that his stock was made tubercular—took tuberculosis—after grazing on the land irrigated by sewage.

1022. And did you make any inquiry into that case?—It had happened a year before I took office, so that it was too late for me to make inquiry.

1023. And you have not known any case since?—No, I cannot tell you of any positive case.

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1024. Should you be disposed to think that there was a possibility of that being true?—I should think it was extremely likely.

1025. Well, now, I heard of a case the other day from a friend of mine; there was gastritis among the cows, and they think it came from drinking from a pond that had been contaminated. Do you think that possible?—Quite. I should say that apart from sewage farms several complaints have been laid before the Rivers Board that cattle have been injured, have died in consequence of drinking from polluted streams. From Liversedge quite lately, at the last Committee meeting, there was a complaint from a farmer that two of his cows had lately died from drinking from a polluted stream. And on the sewage farms it may not be so much that the vegetation is bad for the cows, but that in the case of sewage farms the cattle are very fond of going to the runnels of sewage. It is well known that they will often prefer to drink the sewage, even crude sewage, than clear water where it is available.

1026. Is that so. Do you state that as a fact, that they would drink the crude sewage?—I have seen them; with a clear stream alongside they have gone to the sewage and taken a drink.

1027. They have gone to the sewage?—It is because of the salt taste, I believe; that is my own idea of it.

1028. We were told yesterday that cattle knew how to take care of themselves?—Well, I have actually seen them do this.

(*Mr. Killick.*) Trade effluents—the cattle would avoid a trade effluent, while they would choose sewage; that is what he intended.

1029. (*Chairman.*) You tell us that there is a scarcity of land, and if clay land is unfit for use that fact must, I suppose, greatly reduce the supply of land?—It does greatly, and the configuration of the Riding also reduces the amount of land available, because in many places the valleys are so narrow that no sufficient amount of land can be obtained. I should like to point you if I may to one or two places. At Todmorden a scheme for their sewage disposal has been delayed for a very long time, because the sanitary authority have not been able to meet the requirements of the Local Government Board. They have now met the requirements of the Board, but they have only obtained the necessary land by wholly altering the course of the River Calder, which runs through the land in a zigzag course; they are taking the river to one side of the valley, so as to get the land over which the river now runs, and the land is in close proximity to a considerable number of houses and to the public road. Then in the case of Halifax, their scheme has been practically sanctioned by the Local Government Board; they have only secured the land by taking a field on one side of the river and a field on the other side of the river; they will have to cross the river with their sewage carriers several times. And Sheffield and Huddersfield county boroughs have not been able to obtain land apparently; at least, their schemes do not include land treatment.

1030. Their schemes do not include land treatment. In what position are their schemes; are they applying to the Local Government Board?—I should like to mention the state of matters with regard to the county boroughs.

1031. Yes, do?—At Bradford the works they have at present are only capable of dealing with about one-fifth of the sewage of the borough. The works of a new scheme are now in progress, and this scheme has been sanctioned by the Local Government Board without the provision of any land; a scheme of chemical precipitation and filtration; I suppose because of the impossibility of getting land in that neighbourhood.

1032. Then the scheme has been sanctioned?—Yes, and that includes only chemical precipitation and artificial filtration. Bradford is one of those places which I have been mentioning, peculiarly situated in a narrow valley. Then at Halifax, I have mentioned that their works are useless at present, nothing more than detritus tanks, but their new scheme has been practically sanctioned by the Local Government Board, and that includes chemical precipitation with artificial filtration and land. The land area was not sufficient for the purification of the tank effluent, and artificial filters were insisted upon in addition. In the case of Huddersfield, they have only chemical precipitation and artificial filtration, and their works are only sufficient for about one-fifth of the sewage of the borough. They have given an undertaking to the Rivers Board to extend their works, and make them sufficient within two years. Then in the case of Leeds, I think that will probably answer the questions you have been putting best. The present sewage works are recognised by the Corporation as inefficient; they are simply for chemical precipitation by lime, with settling tanks only equal to about one-eighth of the day's flow—quite insufficient. The Corporation are doubling that capacity, but are also carrying on experiments in the new methods of sewage treatment by biological filtration, and intend to construct complete works for the purification of the whole of the sewage of the borough. If the new methods are adopted, they will be able to get, not within the borough, but in its immediate vicinity, sufficient land for the purpose. If they had to have land treatment they would have to carry their sewage some 17 miles down the river to get a sufficient area of land, and the land that they would get there is perhaps not—certainly not the best kind of land for the purpose; there is a sufficient area of it, but it is not of a very suitable nature. The biological filtration scheme would probably cost about a quarter of a million; I am told the other scheme to take the sewage 17 miles down the river would probably cost about three-quarters of a million; it would make a difference to the city of half a million. In the case of Sheffield their works are also on the lines of chemical precipitation, with, I should say, a pretence at artificial filtration—it is simply a straining through rough coke; but they are also experimenting in biological filtration for the improvement of their works. The tables that have just been handed in are tables of the various kinds of sewage treatment in the Riding. They begin with filtration through land; then there is chemical precipitation or settlement; settlement or chemical precipitation followed by land; chemical precipitation followed by artificial filtration; and artificial filtration only. Some of the sewage works, I must say, are scarcely worthy of the name, but they are all put in, such as they are; there are 233, I think the number is.

1033-5. We should be very glad to hear anything more about Leeds?—In the case of Leeds, my Lord, if you will look at the table of analyses—which give analyses of crude sewage and sewage effluents at representative works of the various kinds in the large tables. At the bottom of the tables you will find the analyses of the effluent from the Dibdin filters at Leeds. The figures given are the average of the analyses of weekly samples taken in the months of April and May. The Leeds Corporation invited the Rivers Board to keep a watch upon the experiments being carried out there, and weekly analyses have been taken. Samples have been taken by the Inspector of the Rivers Board, and the samples have been analysed in the Board's laboratory, and the results there, I think, are wonderfully good, considering the mixed nature of the sewage at Leeds.

1036. Is the sewage that is artificially filtered there—everything lumped up together—trade refuse and the domestic sewage, and everything?—It is taken from the main outfall sewer of the borough; there is at that point only one main outfall, which contains all kinds of sewage, and this sewage which is treated is taken haphazard from the general sewage of the town.

1037. And what about filters?—They have been laid down under Mr. Dibdin's supervision; there are two filters, a rough filter and a fine filter, each of them one-eighth of an acre.

1038. One-eighth of an acre?—One-eighth of an acre, and those have been working since October last, I think it is.

1039. Then you carry the sewage from the outfall, and pour it on to the filters?—Yes, with some screening. For some time at the beginning of the experiments, the sewage was poured on to the rough filter as it came down the outfall sewer, quite in its crude state. It was found that the filters were choking up a little, especially on the surface, with paper and pieces of stick and straw and fibre from the many woollen works discharging into the sewers, and for that reason a screening arrangement was put in. The openings in the screen are, I think, one-sixteenth of an inch in the screening arrangement.

1040. (*Colonel Harding.*) One-eighth of an inch, I believe?—One-eighth of an inch in diameter, so that only the very rough solids are taken out of the sewage now.

1041. (*Chairman.*) Is each filter about one-eighth of an acre?—Yes.

1042. And are they adjacent to one another?—They are adjacent, one at a higher level than the other, so

that the effluent from the coarse filter goes on to the fine filter.

1043. It falls?—It falls on to it by gravitation.

1044. But there is no distance between the two?—No; they are quite adjacent.

1045. The amount of space required for the two is very small?—Only the thickness of the walls beyond the area of the filter.

1046. Could you tell us some of the principal difficulties that you meet with in the disposal of sewage?—Well, I have spoken already of the nature of the land and of the scarcity of the land. The third important difficulty is the nature of the sewage.

1047. The fact of its being mixed with trade refuse?—Trade effluents of all kinds; this mixture of trade refuse with the sewage makes it very much more difficult to treat.

1048. Do the manufacturers treat their own refuse at all in many cases before it leaves their own premises?—That is a thing which is only now coming under the consideration of the manufacturers. Recently the Rivers Board has been calling the attention of the sanitary authorities to the inefficient treatment of the combined sewage, and the sanitary authorities answer that they have great difficulties, because of the amount of solids sent them by the manufacturers, and because of the nature of the trade refuse. And then it has been pointed out to the sanitary authorities that it is possible to remove a great part of this from the trade refuse before it is discharged into the public sewers.

1049. That is to say, before it leaves the premises of the manufacturer?—Yes.

1050. And do you find the manufacturers generally willing to do what they can?—In all cases, my Lord, they are quite willing to take out from their trade refuse anything that will interfere with the treatment of the sewage if the sanitary authority will receive this partially-treated effluent into the sewers. It has been done in a great many districts now—in Leeds, in Keighley, which is quite a manufacturing town, in Horbury, Pudsey, Farsley, Shepley, and Wetherby.

1051. What do you find a manufacturer would generally do? Would he build a tank within his works in which the solids could settle?—That is so; he is generally asked to take the solid matters out of his trade refuse.

1052. Well, then he does that by building a tank?—A settling tank.

1053. A settling tank?—Yes.

1054. And then do you see any particular reason why he should not be further asked to put up a cheap filter for the effluent from that settling tank?—You mean with the intention of discharging the effluent into the streams afterwards?

1055. I mean, to have not only a settling tank, but also a filter on his own premises. I do not mean to say, of course, every small man, but the large places?—But with the view of discharging the effluent into the sewers or into the streams?

1056. Well, wherever you like?—Because the two things cause very different expense to the manufacturer. If he is only going to sufficiently purify his trade refuse for its discharge to the sewers a very much less expensive apparatus would be required than if he is going to purify it sufficiently to discharge it to the stream; a much greater amount of settling room would be required, and a much better arrangement for filtration, if he is going finally to discharge into the stream.

1057. But now, the question of room; all that he wants room for is room enough for the solids to settle, is it not?—If he is going to discharge into the sewer?

1058. Well, let us take the question of the sewer by itself?—May I put it this way, my Lord? In the case of his getting permission to discharge his trade refuse to the sewer, he only requires to partially purify it; if he is going to discharge it into the stream, he requires to fully purify it, and the cost in the latter case is very much larger than in the former case.

1059. If we take the question of discharging into the sewer; he has a settling tank, in which, as I understand, all the solids ought to remain?—Well, they ought to, but they do not.

1060. They do not?—The sanitary authority do not require the manufacturer to have sufficient settling room to remove all the solids from his effluent.

1061. It does not amount to that?—It does not amount to that.

1062. It would be a great advantage if it did?—It would be a great advantage if it did certainly; it would lessen the trouble of treating the combined sewage at the outfall.

1063. Suppose a manufacturer had a tank big enough to retain all his solids? I do not know whether you know Mr. Cameron's system?—Yes.

1064. It is claimed for this system that it is applicable to the smallest places as well as the biggest?—Yes.

1065. And that you only want a tank and a filter. Now I am not asking your opinion as to that particular system, but supposing there was an effective process that required very little space, should you think it very unreasonable to ask big manufacturers to have their own tank and their own filter-bed?—I do not think it would be at all unreasonable if they cannot obtain admission to the sewers, and many of them will be unable to obtain permission to the sewers.

1066. But even if they do obtain admission to the sewers, it would be, I suppose, a great advantage to have their effluent filtered before it gets into the sewer, because, presuming the effluent to be filtered before it gets into the sewer, would not that have a great effect in removing the difficulties that are caused by the mixture of trade refuse and sewage in the sewer?—Oh, yes, it would be, and for some classes of trade refuse, I think, it is necessary that filters should be provided.

1067. Before they get into the sewer?—Before they get into the sewer. May I point out, my Lord, certain conditions which have been laid down by the Keighley Borough to their manufacturers; they are the fullest and most definite conditions that we have in the Riding, and you will find filtration mentioned, if you will allow me to go into them. The first of them is that "The "volume of waste water shall be reduced as far as prac-"ticable; as, for example, by keeping condensing water "and surface water out of the drains." Then it says that "All trade waste waters, except suds, shall first be passed "through coke filters."

1068. Oh, yes, on a down and an upward principle?—Yes.

1069. That is going into it very thoroughly?—Yes. What they have to deal with there is trade waste from wool washing (that is the suds mentioned here), dye-waters, and tanners' refuse. Now, the dye waters do not require any preliminary treatment except the removal of the solids, and, of course, this filtration will remove the solids from them. The tanners' refuse can be treated along with the general sewage if gross solids are taken out. Then the third paragraph, you will see, deals with the suds; the grease is to be removed, and the liquid to be drawn off by means of a floating arm. Now, I believe, in this case too, the Corporation requires that a filter should be provided, so that the whole of the effluent should be filtered through coke before it is discharged into the sewer.

1070. That, of course, is asking a great deal to be done. Do the manufacturers agree to those conditions?—They are glad to agree, my Lord.

1071. They are?—If they did not agree with the Corporation, they would have to agree with the Rivers Board, which would ask much more than this—not much more in principle, but much more in the capacity and the cost of the works they would have to erect.

1072. The Corporation make these conditions for admitting them into the sewers?—Just so.

1073. If they did not agree to them, where would the Rivers Board come in?—If this refuse were not admitted into the sewers, it would have to be discharged into the streams.

1074. Quite so; I see what you mean. Have you anything more to say about what is being done to deprive the trade refuse of its injurious properties?—It is one of the things that is being very much discussed in the Riding at present. Only so late as last year the Bradford Corporation passed an Act through Parliament, a private Act, allowing them to call upon the wool-combers in the borough to treat their suds for the removal of the grease before discharging it into the sewers. And in a great many cases the authorities are considering what conditions they shall impose upon the manufacturers with the view of allowing them afterwards to turn their refuse into the sewers.

1075. Do you consider it reasonable that trade refuse should always be dealt with by the sanitary authority?—It cannot be in all cases.

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1076. It cannot?—There are certain cases where it would be impossible for the sanitary authority to allow the manufacturers; there are several mills in the Riding discharging over a million gallons of refuse a day. Well, that would swamp the sewage disposal works unless they were enormously increased in size. Moreover, it would remove all the volume of water from the streams and the riparian rights would come in.

1077. Then those million gallons are going into the river, are they?—Yes.

1078. And polluting the river?—And polluting the river, requiring treatment.

1079. And do they go in without any treatment at all?—Well, the cases vary. In at least one case they are going in at present without any treatment; that is from a dye works in Leeds. In a case in Bradford, they have very inefficient settling tanks, and they are under notice of proceedings by the Rivers Board to make efficient their works for the purification of the waste. In a case in Halifax they have disposed of this refuse; they have not told us how, but I believe they have turned it into the sewer.

1080. They have turned it into the sewer?—Yes, I believe so.

1081. In the case you mentioned in Leeds, where it is going in without treatment at all, do the Rivers Board leave that alone?—Oh, no, my Lord; proceedings will be taken against the manufacturer for the purification of this refuse.

1082. And then he will be made to treat it in the best way he can before it goes in?—Yes. If he can obtain permission from the Corporation to drain into the sewers that will be done, no doubt.

1083. But otherwise he will have to treat it in the best practicable manner?—That is so. In that case he draws a great deal of water from the river, and one of the riparian owners, or, rather, the Navigation Company, the Aire and Calder Navigation Company, would not allow him to turn his refuse into the sewers; they want to have the water in the stream.

1084. Then he will have to fight that out with them?—Yes. The Rivers Board has always stood absolutely neutral between the manufacturer and the sanitary authority. If the sanitary authority will allow the manufacturer to drain into the sewer, that is for them to decide, but if they will not, then the manufacturer is compelled by the Rivers Board himself to purify his trade waste.

1085. And now with regard to the sewage works that have been put up. Do you consider that they have been, the large proportion of them, successes or failures, or the one or the other?—There have been, I am sorry to say, a large amount of failures.

1086. More than you would have expected, or, I mean, more than you would have hoped?—Well, the causes of failure have been so various, that I do not think they have been more than could have been expected. Many of the sewage works were quite inefficient from the start, were not made large enough for their purposes. Take some of the country boroughs, for instance,—the Bradford works were constructed twenty years ago, more than twenty years ago, and from the very beginning they have not been capable of dealing with the whole of the sewage of the borough.

1087. Were they put up meaning to deal with the whole of the sewage of the whole borough?—They must have been so, but they have not been dealing with the whole of the sewage from the very beginning. I think Huddersfield works were constructed in 1893, and they were built to deal with 4,000,000 gallons a day; they are really only found capable of dealing with something over 2,000,000 gallons.

1088. They were built for 3,000,000?—For 4,000,000.

1089. And can only do a little over 2,000,000?—A little over 2,000,000, and the sewage reaching them is now something like 10,000,000 gallons a day, so that the rest of the sewage goes to the stream. Then it is the tendency of things in the Riding for the boroughs to increase their boundaries; they are constantly taking in parts of the rural districts around, or absorbing urban districts, and they always undertake to purify the sewage of the district which is taken in; but they have not been increasing their sewage works.

1090. There is the failure from the size. Well, then as to the way in which the sewage is treated?—Many, of course, of the old methods of dealing with the sewage are inefficient; I think that is now generally recognised. Where only chemical precipitation is used, the works have of necessity been found inefficient.

1091. Is much attention paid to the management of the works?—Better attention has been paid recently since the Rivers Board has been supervising the works, but very frequently sewage works have failed in purifying the sewage because of the mismanagement. In the smaller districts a great many of the works are put into the hands of a roadman, or of someone without any training in the subject whatever, and in many cases the land upon which the sewage is treated is let to a farmer. In those cases it very frequently happens that the works are mismanaged, even though they are capable of dealing with the sewage; so that the result is unsatisfactory.

1092. Has your Board got power to come in in that case where the sewage farm is let to a farmer?—No.

1093. We had evidence, yesterday, that that was very objectionable; but you cannot help it if the authority lets it?—Well, not directly. The Board can take proceedings, of course, if the effluent from the sewage farm is not satisfactory. But what has been done is this: In the case of Settle Rural, the sanitary authority have let three of their sewage farms to farmers, and the farmers, as is nearly always the case, got the best crops they could from the land and let the sewage go to the stream. The Board asked me to interview the sanitary authority and to visit the farms with them, and I did so, and pointed out to them the gross mismanagement because of this method that they had adopted, and in consequence of that they have taken the management of the three farms into their own hands.

1094. They did take the farms?—They did take them, with good results since.

1095. But you would not have power to insist upon their taking it into their own hands?—We could not, except, quite indirectly, by taking proceedings against the authority for polluting the streams.

1096. Are there any sewage works that are a source of profit to the sanitary authority? When I say "source of profit," I mean a legitimate source of profit?—I do not know of any in the Riding that are a legitimate source of profit. The sanitary authorities let the land, as I have said, sometimes, and get a rent for it in that way, but the treatment of the sewage suffers. In many cases they get some return from crops, which partly pay the cost of management; but I do not know any works where they pay all the costs.

1097. Do you think it necessary that sewage works should be constantly supervised?—Oh, it is quite necessary. A great change has taken place in the Riding since the Board began to supervise the sewage works. I may point to things that have been found by the Board's inspectors to best show that. In many instances, the sewage works were closed at night, the man in charge left them shut down, and turned all the sewage into the stream by the storm water overflow.

1098. Did they really?—Frequently; sometimes still we find that is done, and storm water overflows are constantly misused even yet. The inspectors of the Board are finding constantly that after a little shower of rain the sewage is directed down a storm water overflow, and I have put in my statement one case where the manager, when he went for his dinner, usually turned all the sewage down the storm water overflow, and gave as his reason, that rain might come on while he was away.

1099. Can you tell us how a storm water overflow is usually constructed?—The commonest kind, I am afraid, in the West Riding, is an adjustable one. There is an overflow provided on the outfall sewer and, beyond it on the sewer, a sluice which can be shut down by the man in charge. If he shuts the sluice wholly down then the whole of the sewage goes into the stream; if he shuts it only partially down, then part of it goes into the stream and part into the sewage works.

1100. Where is the storm overflow usually constructed? Is it near the outfall of the sewer?—Well, it varies very much. The districts in Yorkshire are exceedingly hilly, and the sewers usually come down from the higher parts of the districts with a very rapid fall and discharge into a flat sewer along the valley. Now, at the point of junction of the rapidly falling sewer and the flat sewer there is very frequently a storm overflow put in. If it were not so, when

the storm water, the surface water, is taken into the sewers, the sewers are charged at once by the great rush of water from the hillsides, and, in some instances, the manhole covers are blown off by the tremendous volume of water coming down. Then, again, the commonest place for a storm water overflow is somewhere on the main outfall sewer before it reaches the works.

1101. Before it reaches the sewage works?—Before it reaches the sewage works, or just at the sewage works themselves.

1102. Just before it goes to the sewage works?—Yes, just before it discharges into the tanks, so that the overflow may be under the charge of the manager of the works. There are really three chief forms of storm water overflows. The second form is a leaping weir; it is briefly of this description:—In dry weather, the sewage goes to the works, it falls into a chamber and reaches the works; in wet weather, the sewage is greatly increased in velocity and leaps across this chamber into an outlet which leads it to the stream, so that in wet weather, when a great deal of surface water is coming down the sewers, all the sewage is frequently discharged in that way into the stream; none goes to the sewage works. And recently, in nearly all recent schemes, it has been the policy of the Rivers Board to ask for, and it has been the policy, I think, of the Local Government Board to insist upon, fixed and automatic storm overflows, which are really in the form of a side weir on the main outfall sewer. When the sewage in the main outfall sewer reaches a certain height, the excess goes over the weir; but there is always a certain amount going to the sewage works.

1103. I see. Then that would remove the possibility of people shutting down the sluice and all that sort of thing?—That is so.

1104. In fact, that kind of storm overflow could not be abused?—No; and that is what the Rivers Board has always insisted on, that when there are sewage works they should always be used to their utmost capacity, whether the sewage is diluted with rain-water or not, that the sewage works should be working to the full before any excess sewage is discharged into the river.

1105. The next point, I think, is the question of the sludge. What do you do with the sludge that remains behind at the sewage works?—It is really one of the great difficulties in the Riding. Enormous quantities of sludge are produced; at Leeds they are producing, with quite inefficient settling tanks, 200 tons a day.

1106. Two hundred tons a day?—Two hundred tons a day, out of some 18,000,000 gallons of sewage, and there they do not know what to do with it. They cannot get rid of it, but they have been renting fields upon which to tip it. In the case of Huddersfield, also, they have taken land upon which to tip this sludge, and let it remain; and also at other places—Yeadon and Tong and Sheffield—there are huge masses of this sludge lying.

1107. Do you mean that they hire fields and throw it out as a sort of dust heap?—That is it; they make a tip for the sludge there.

1108. Is not that very offensive to the neighbourhood?—It is in some cases very offensive. I may add, my Lord, that in the case of Sheffield, the Board has had to call upon them to treat the water draining from this sludge-tip, to construct sewage works, just as if they were purifying the ordinary sewage; the liquid that drains away is quite as bad as sewage, sometimes worse.

1109. In the sewage works where no sludge is produced this trouble is got rid of, but have you any sewage works where no sludge is produced?—In all the sewage works where the sewage is treated on land, irrigated in its crude state upon land, there is, of course, no sludge.

1110. Oh, no?—But what I referred to in my statement was, that if this method, for instance, being experimented upon at Leeds is successful, then they will get rid of the sludge difficulty wholly; the sludge is destroyed in those bacteria beds; it is dissolved, and goes away with the effluent.

1111. But then you have got nothing of that sort yet; though that is what we are all hoping to get?—Well, there are those experimental tanks at Leeds and other places, and the three works which I have mentioned upon which I have not expressed any opinion; three complete works have been constructed; I mentioned those at Thurnscoe, at Horsforth, and at the Cookridge Hospitals in Leeds.

1112. It is too soon to express any opinion?—Yes.

1113-4. Have you any sort of suggestion to make as to any better disposal of the sludge than throwing it on to a dustheap?—I am afraid I have not; it is exceedingly difficult to dispose of it. The farmers will not take it, and it has been even suggested that it should be carried down to the sea from the Riding, but that would be at an enormous expense.

1115. At an enormous expense to you, of course?—Yes. There have been proposals to burn it—there is at least one patent method by which it is proposed to burn this sludge, but it is not in action at any place that I know of.

1116. Has it ever been tried that you know of?—Experimentally it has been tried.

1117. But you do not know at all whether successfully or not?—Well, it was tried experimentally at Bradford, but I know that the Corporation were not satisfied with the results.

1118. They were not?—No, it was by the admixture of a little peat with the sludge, and the Bradford sludge contains a great deal of grease, which would make it more combustible than ordinary sludge.

1119. Is your Board represented when there is an inquiry by the Local Government Board?—Yes; the clerk and myself have been directed to attend all Local Government Board inquiries into sewage disposal schemes.

1120. And have you anything to say to us upon that head?—Well, it would be a very good thing, I think, if the Rivers Board were made aware of the details of sewage disposal schemes before inquiries were held. At the inquiry is our first opportunity of knowing what the scheme of the authority may be, and always, I think, we are able to point out one or two particulars in which the schemes can be amended. We have the local knowledge, of course, which the Local Government Board inspector cannot have.

1121. The only thing is: Do you think the sanitary authorities would not look on that as undue interference?—I think not, my Lord; it has not been the experience of the Board in the past; they have always met us in a friendly way, and nearly always have accepted our suggestions, and very frequently of late the engineers of schemes have, unofficially I should say, asked us to look at their schemes before submitting them to the Local Government Board.

1122. Do you think it would be advantageous to treat sewage of adjacent authorities as one joint sewage works?—That is a thing that really should be done in many places in the West Riding, because of the configuration of the country, and because the river valleys are so often populous for their whole lengths, with very short breaks without houses. It is frequently necessary to have the sewage works of two or three districts combined. It has been done in several places; I may mention Brighouse.

1123. With advantage?—With great advantage.

1124. How does the River Board deal with the offending sanitary authorities?—The usual procedure of the Rivers Board has been, first, to caution any offending authority, and if the caution is not sufficient to get the matter attended to, then the authority is asked to send a deputation to a meeting of the Committee dealing with sewage pollutions, and after this meeting, the authority is asked to give an undertaking to take certain measures to put a stop to the pollution. For instance, if they have no sewage works, they are asked to submit plans of a scheme to the Local Government Board within a certain definite time. If they do not give this undertaking, or if they do not adhere to it when it has been given, unless they have some sufficient reason for departing from it, proceedings are taken, and an Order of the Court obtained. But proceedings have been taken in very few cases indeed in the Riding. All the work which is shown in the remarks on Tables D, and also on page 2 of the Annual Report, which has been submitted, has been done with proceedings only in two cases.

1125. You have handed in a report of the number of trades pollutions in the West Riding?—That is the larger report, my Lord.

1126. Does that report show the condition of things when the Board was established?—No, my Lord. I am sorry there is no report showing actually the condition

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of things then. This survey took a long time to make, and the last part of it was only handed in to the Board last December.

1127. Then the improvements which have been effected since are marked in the report?—Yes, they are marked in red ink.

1128. But those improvements are only since the date of the report?—Since the date of the report. Many things had been done before the report was given, especially the latter part.

1129. You have different kinds of liquid refuse to meet with there: coal-washing, leather trades, brewing, paper works, wool trade, bleach works, silk works, iron works, chemical works, gas works, soap works, malting, corn-washing. Those, I suppose, are the principal of them?—Yes, those are the principal, and then there are some unclassified trades all lumped together.

1130. Now, when you come to deal with a manufacturer, how have pollutions been reported to the Board?—They were reported, in the first instance, according to this report, trade by trade. It was felt by the Board that it was better to deal with each trade separately, so that no cause for complaint should be given to one manufacturer in one part of the Riding that he was being dealt with, while his neighbour at some other stream at a distance was being let alone, and so far nearly all the action of the Board has been taken trade by trade. But recently, since this report was completed, and, indeed, before it was completed, various reports had been given to the Board upon individual streams. These reports will be completed for the whole Riding by degrees, and in them each stream is dealt with separately. All the pollutions in each stream are mentioned in detail, both from domestic sewage and from trade refuse, and then most likely the trade pollutions will be dealt with stream by stream.

1131. And what steps does the Board take to stop that pollution?—The steps are really very much the same as in the case of domestic sewage. A polluting manufacturer is first warned, and if he does not heed the warning and construct works of purification, or get permission to turn his refuse into a sewer, he is asked to appear before the Committee dealing with trade pollutions, and to show them cause why legal proceedings should not be taken against him. In most cases at this interview with the Committee he gives an undertaking to deal with his trade pollution within a fixed time, and if he refuses to give this undertaking, or does not carry it out, then the Committee usually recommends the Board to take proceedings against him, and legal proceedings are taken against him.

1132. In how many cases have legal proceedings been taken?—Most of the work has been done as in the case of sewage pollutions, by the Committee of the Board, and legal proceedings have only been commenced by summoning the manufacturer before the Board in sixteen cases, and real legal proceedings have only been commenced by application to the Local Government Board in two cases. Before the Courts an order has been obtained against a manufacturer in one case; in the other case the Local Government Board gave leave to prosecute, but the proceedings were postponed, because an inquiry was to be held into his right to drain into the public sewers, or at least involving the decision of his right to drain into the public sewers, and that inquiry was only held yesterday.

1133. You have had very little legal proceedings?—Legal proceedings—very few.

1134. You have found them very reasonable then?—The great cause of delay, I think, is that the manufacturers do not know exactly what their legal position is.

1135. They do not?—There are a great many cases hanging upon this decision, which will be given upon the case inquired into by the Local Government Board yesterday; they do not know whether it is their own duty or the duty of the sanitary authority to deal with their trade refuse.

1136. What is the case that is being inquired into exactly?—It was the case of a certain manufacturer in the wool trade. Application was made by the Board to the Local Government Board for permission to prosecute him, and permission was given after local inquiry. Then he applied to the Local Government Board under the Public Health Act, Section 299 I believe it is, making a complaint that the sanitary authority had not provided sufficient sewers for the needs of their district; that is, that they had not provided sewers sufficient to take his trade refuse. There is a sewer which passes his mill and which takes all the domestic sewage in the neighbourhood, but he claimed that he should have the right to turn his trade refuse in, and the authority had not provided sewers and sewage works sufficient for that. The inquiry by the Local Government Board was into that complaint.

1137. His complaint that there were not sewers enough?—Yes.

1138. Then what do you do when sanitary authorities without sewage works undertake to deal with trade refuse?—We have many cases of that kind, and when a sanitary authority without sewers or sewage works undertakes this the Board has asked the sanitary authorities upon what conditions they will admit trade refuse—that is, what preliminary treatment of the trade waste they will require from the manufacturer. Whenever they decide upon those conditions the Board asks the manufacturer to comply with those conditions at once, not recognising them as sufficient for the purification of his refuse before he turns it into the stream, but recognising that it is not just to ask him to put down expensive purification works, if afterwards, within a year or two years, he is going to get admission into the sewers. And in the meantime, by the works that he constructs to take out the solids to satisfy the sanitary authority, so much purification of the stream is got,—the solids are taken out.

1139. What can be done by a manufacturer whose works are surrounded by houses?—There are several very difficult cases indeed, and when a manufacturer's premises are in the middle of a town he has been always, I think, asked to approach his sanitary authority to see if they will not admit his refuse into the sewer. If he cannot get that permission then it is open to him to adopt some of the patent methods of purification which take up less room than the ordinary settling tanks and filter beds. There are several instances where the manufacturers are adopting methods of that kind.

1140. Can you describe one at all?—There is the method of Mather and Platt, a patent settling tank it really is, in which the sludge is blown up into the liquid in the tank each time the tank is used, and assists in depositing the remaining sludge in the trade waste. It really is a settling tank which requires to be of less capacity than the settling tanks on ordinary principles. Then there are several kinds of filters.

1141. When a mill is taken on a yearly tenancy, whom do you consider responsible?—The person responsible under the Act is the manufacturer who discharges refuse into the stream.

1142. However short a lease he has got?—However short a lease.

1143. And do you deal especially with new pollutions?—That, I think, is one of the defects of our Act, and of the Rivers Pollution Prevention Act, that new pollutions must be dealt with in exactly the same way as old pollutions.

1144. Oh, they must?—There is no summary way of dealing with them.

1145. Do you get questions about riparian rights arising?—That is a very serious question on many of the streams in the Riding. On some of the smaller streams the water is used over and over again. In one case, Batley Beck, in the course of seven miles from the source of the stream to the Calder, there are sixty mills on the banks of the main stream, perhaps as many again on its small tributaries, and each of those mills is drawing water from the stream. In the upper reaches they use it for manufacturing processes; in the lower reaches they use it either for boiler purposes or for condensing water. They are at present turning that water back into the stream. If they all turned it into the sewers there would be no water in the stream in the lower reaches. And then again, in the case of one of the Becks in Leeds, there are a great many large tanneries, the effluent from which is of a very polluting character, far worse than ordinary town sewage, and owing to the work done by the Board most of the tanners have constructed works for the preliminary purification of this refuse, and have been allowed to discharge their effluents into the town sewers. Now the Aire and Calder Navigation Company, who have special powers under special Acts of Parliament, have served notice of proceedings both upon the Corporation, I believe, and upon the manufacturers because they have abstracted this water from the stream.

1146. Do you find any trade pollutions which the Rivers Board cannot deal with?—The great trade pollu-

tion which the Rivers Board has no powers for dealing with is that of ochre water from mines. From many of the mines at the head reaches of the Don and Calder Valleys a large amount of ochre water resulting from oxidation of iron pyrites is discharged, and this water is very acid. In one or two instances where it was examined, there were seventy grains per gallon of free sulphuric acid in it, and when it is used for boiler purposes it quite spoils the boilers of the manufacturers—corrodes the plates.

1147. Do you mean that you have no power to deal with it, or what?—It is specially exempted by the Act.

1148-9. Is it?—That water pumped from mines, as it is pumped from the mines, is exempt from the provisions of the Act

1150. Now can you tell us in what cases the waste products are recovered from trade refuse?—There are several of the trades in which this has been done. In the wool trade the waste grease is recovered in very many cases. If I may direct your attention to the big report you will find "seak tanks" mentioned in many instances. The "seak tank" it is called. That is, a process for recovering the grease from the wool comber's suds or from the piece scouring or milling suds. Then, in the case of coal washing, I think in practically every case it has been a great saving to the collieries that the Rivers Board has made them purify their waste waters. In one case the manager of a colliery has told us that he has saved 300 tons of coal a fortnight because of the measures he was made to adopt. There it is made into coke; in other cases it is burned under the coke ovens. Then in the case of paper works, in several of the paper mills they re-use all the sludge which they collect from their trade waste. In the case of bleach works there has been a great saving in one or two cases, because they do not discharge the chlorine water that they used to discharge—the bleaching liquor. In the case of the iron trade there is some return to be made from the crystallised copperas (ferrous sulphate) which the iron liquor contains. And in the chemical works in several instances the manufacturers have at least partly recouped themselves for the expenses of purification plant—at soap works glycerine plant has been constructed in many cases.

1151. Is there the same sludge difficulty with trade refuse as from domestic sewage?—It is quite as bad, perhaps even worse, because much of the sludge from trade refuse has no manurial value. It has generally to be got rid of by tipping it on waste land or by getting rid of it along with the cinders of the mill.

1152. Where would the sludge accumulate—on the trader's premises, I suppose?—In the first instance.

1153. Well, then, he has no right to take that and tip it on to waste land?—Unless the land belongs to him.

1154. But as a general rule is that what happens—that he tips it on to land that does belong to him?—As a rule that is so.

1155. And then there it remains—a nuisance the same as the other?—Just the same as the other. In many cases the manufacturer tries to make use of it on agricultural land if possible, but the manurial value is evidently very small. In other cases he tries to burn it, in some few cases with success, but usually it contains so much moisture that it costs more to burn it than any good he gets out of it in steam raising.

1156. In the case of a man who has no land of his own, what does he do?—There are very few cases where it is altogether impossible to obtain land.

1157. I see?—I do not think we have met with any case of the kind yet.

1158. He can always throw it away on to his own land somewhere?—He has already in most cases cinders to get rid of from his furnaces, and he can get rid of his sludge in the same way as he can get rid of his cinders.

1159. He has got somewhere that he can deposit it?—Yes, there is some outlet for it. Perhaps before you leave the previous question I might say that in a good few instances the manufacturers are making a claim that if they have to construct purification works the sanitary authorities should at least remove their sludge for them. That claim has been made in several cases. I do not know any case where the sanitary authority has done so?

1160. Has the Rivers Board adopted any standard of purity there for the sewage or trade refuse, or purified trade refuse?—No. They have been frequently asked to say what standard of purity they require, but they have always refused to state any standard. They have found it impossible to fix any standard applicable to all cases.

1161. There was just one thing more I wanted to ask you about the experiments in Leeds. You told us that the whole of the sewage, combined trade refuse and sewage, together was being experimented upon?—The whole of the sewage was for several months treated exactly as it reached the outfall, but I think I said that now lately it has been screened to get rid of the grosser suspended solids. *Dr. H. M. Wilson, M.D., B.Sc.* 14 July 1898.

1162. You began by simply catching it at the outfall, and pouring it straight on to the filters?—That was so.

1163. And then the solids, I presume, rather stopped the action of the filter—choked it?—They did not choke the filters at all, but they began to form a sort of felting over the surface, and it was thought that this felting of straw——

1164. What do you call it?—A felting material, a coating, a matting of the straw and paper, and small pieces of wood, orange peel, and fibre from the mills; woollen fibre formed a coating on the surface of the coke, and it was thought that this coating would prevent the proper aeration of the filter. To prevent that the screening arrangements were put down.

1165. Then have you practically found any difference since the screen was put down?—No difference that could be ascribed to the screening.

1166. No difference?—Other alterations have taken place in the way in which the filters were worked. They were for a long time charged thrice a day; of late they have been charged twice a day, and the result has been very much better since they were charged twice a day than before.

1167. I am not quite sure that I understand what you mean by charging?—The way in which the filters are used in this. The sewage is run into the first filter—the coarse filter—which takes about an hour to fill. The sewage remains in that filter, being kept back by a valve for some two hours; then the valves are opened, and the sewage runs out of the filter slowly. It takes about an hour, roughly speaking, to empty the filter. Then the filter remains empty for a certain period. Each is used in periods of eight hours. Changes have taken place from time to time in the way the filters are worked, so I may be making some mistake in the way in which they are used now. But I think there is allowed four hours for the filter to rest for aeration, no sewage being in it. Then the filter is filled and allowed to stand full of sewage, and slowly emptied again.

1168. Then one lot of sewage took eight hours?—Yes.

1169. And now you do it oftener than that?—No. It is still, I believe, used in the same way, only the filter instead of being charged three times a day, that is, in three shifts of eight hours in the twenty-four, it is now charged twice during the day, and in the night-time it is stopped off, because it is more convenient to work the filters by daylight, and the night hours are given for rest and aeration. I believe that is what is done at present.

1170. And you consider that that has improved it?—Very much so.

1171. But you do not find that this felting over the top, as far as you saw, did any harm?—I do not think that one could prove that any harm resulted from it.

1172. But, if it went on long enough, I suppose, it would become impermeable?—Yes, that was really the fear, that it would coat the whole surface of the filter, and prevent the air getting in.

1173. (*Mr. Killick.*) The area under the jurisdiction of the West Riding of Yorkshire Rivers Board roughly coincides with the watersheds of the rivers you have mentioned?—Yes. There are, as I have mentioned, one or two top waters of Lancashire rivers in the Riding, but practically it is the watersheds of the rivers that go to the Humber.

1174. Can you say anything as to the relative efficiency of the sewage works, and the manufacturing effluents since the formation of the Board? Can you give us any figures as to what was done before the Board was formed, and what has been done since?—In the annual report on the second page, which was presented, I think, to the Commission—it is not in this statement, but it was presented to the Commission—there is a statement of the number of sewage disposal works in operation in 1896, in 1897, and in 1898, showing the relative position of the works in operation, works in progress or sanctioned by the Local Government Board, schemes before the Local Government Board, and schemes in preparation.

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1175. Well I will put the question in another way. Since the formation of the Board, has the pace of providing for the treatment of sewage been accelerated?—Oh, yes, very greatly.

1176. Very greatly accelerated?—Very greatly.

1177. And that is also true of manufacturing effluents?—Yes. Would you allow me, sir, to add that, of course, some of the work now being carried on by the Rivers Board was being done by the County Council before the formation of the Joint Committee.

1178. When did the County Council begin to treat sewage works?—They were established in 1888, and almost immediately, I think, began to take up the question of rivers pollution.

1179. I will take you to the treatment of sewage. Broad irrigation on land, I presume, you consider the best means of treating sewage?—It depends entirely upon the character of the sewage, and upon the character of the land. Broad irrigation on land for the sewage of manufacturing towns is, I am quite sure, a failure generally, and broad irrigation on land, that is, without any previous treatment—broad irrigation on land of the nature of which it is in many instances in the Riding, is also a failure where the land is very stiff clay.

1180. You say broad irrigation on land, without regard to its quality of sewage effluent for a manufacturing town exactly, means a failure?—Yes, it has been found so in many cases in Yorkshire.

(*Chairman.*) I am very ignorant, but will you tell me what broad irrigation is?

1181. (*Major-General Carey.*) I think that broad irrigation is the disposal of crude sewage on land without any preliminary treatment. There may be subsidence tanks, but otherwise there is no previous treatment?—I think I would add to that, if I might, that crude sewage might be disposed of on land not by broad irrigation, but on the intermittent down filter.

1182. Well, I am assuming broad irrigation; you have a population which suits broad irrigation, that is, the 100 of population to the acre.

(*Mr. Killick.*) 300 to an acre.

(*Major-General Carey.*) We have said 300 to an acre, but it has always been an excess; in nineteen towns of England, the largest towns in England, the average is not more than 149 per acre.

1183. (*Mr. Killick.*) But Dr. Wilson's answer is distinct, that for the sewage of a manufacturing town, broad irrigation is not always the most successful treatment?—Would you like me to give you instances of that?

1184. I should be obliged?—Because I have instances. Those cases that I have are not cases of broad irrigation of crude sewage; they make the case even stronger in support of what I said. In the case of Otley, which is in the Wharfe Valley, there are sewage works only six years old. They were sanctioned by the Local Government Board in 1892, I believe, and they have precipitation tanks and land laid out for intermittent downward filtration; that is, the sewage is applied to one plot for a time, until it refuses to pass through the soil, then it passes on to another plot, giving the first time to rest. The land at Otley sewage works is exceptionally good for sewage treatment, but because of the amount of trade waste mixed with the sewage, the works have become wholly inefficient; the land has become thoroughly silted up, and the authority has been threatened with action for causing a nuisance, because the sewage stood in pools on the land, and became very offensive to the neighbourhood.

1185. What extent of land to the population have you?—Five acres of land to a population of some 7,000.

1186-7. You see that is very much less land——

(*Major-General Carey.*) That would not be broad irrigation?—That is after precipitation of the solids.

1188. (*Mr. Killick.*) That is not my question; the question is, with broad irrigation, and a proper amount of land—that is, an acre of land to less than 300 persons—do you still repeat your opinion that a manufacturing town's sewage cannot be most efficiently treated on that?—Yes, I do, sir, for this reason, that even in these cases, as at Otley and Burley (Burley is a place where there is no chemical precipitation, but at Otley there is chemical precipitation, which removes a great part of the solid matter from the sewage), the land is not capable of dealing with it.

1189. Can you give us any illustration of broad irrigation with a sufficient acreage of land that has been a failure? There is not sufficient acreage here?—Not for the treatment of sewage by land alone.

1190. No?—I am afraid I cannot; it has not been tried. There is the case I gave of Eccleshill, where they have eighty acres.

1191. With what population?—To a population of—there, again, they have too large a population; I am afraid I cannot give you the exact population draining into these works.

1192. (*Major-General Carey.*) Eccleshill, would it not be quite 7,500?—Yes, but they have two sewage works there.

1193. Eccleshill urban, eight acres, 7,500 population?—Yes, that is my list, 1,500 houses; but I cannot give you any place where sufficient land is used for combined trade waste and domestic sewage.

1194. (*Mr. Killick.*) Then as between the two systems with all their variations and precipitation and land filtration, which may be described as artificial filtration, can you give any opinion as to the relative merits?—I would not like to give any definite opinion, because it is not based on a large number of analyses. The laboratory of the Rivers Board has only been established some nine or ten months, but I have given one or two analyses of each kind of sewage effluent in this statement, and beyond that I should not like to give any definite opinion.

1195. You spoke of it being advisable to establish joint boards for the treatment of sewage. Are you aware of any powers existing anywhere by which authorities can be compelled to make joint boards?—No, I do not think there is any such power. The Rivers Board has used its influence by calling authorities together before them to get them to combine in schemes of sewage treatment, and they have been fairly successful, but they have no actual power.

1196. With regard to the standards, you are not in favour of standards being fixed?—No, I have advised the Rivers Boards that it is impossible.

1197. You are probably aware that for the purposes of classification the Mersey and Irwell Joint Committee have adopted what they have described as "limits of impurity"?—Yes.

1198. Those limits of impurity are one grain per gallon albuminoid ammonia, one quarter grain oxygen absorbed, any test, one grain oxygen absorbed four hours test?—0·1 grain a gallon of albuminoid ammonia, I think it is.

1199. ·1 yes. Do you think these are fairly satisfactory tests for the purposes for which they are used?—I may say that I myself have taken the same as a working test. I have consulted several of those officers of county councils and Rivers Boards who are concerned in the same work, and after hearing what standards they took, and the experience that I have had in the Riding, I have taken those very standards.

1200. And you find, as a rule, that the albuminoids ammonia test and four hours' oxygen absorbed test agree roughly?—Roughly they do, yes. I think I should like to add, if I may, to what I have said, that a chemical standard alone does not seem to me to be always quite a fair standard, because the effluent from a sewage farm where chemical methods are used, compared with that from a sewage farm where land treatment is adopted, or where the modern methods of biological filtration are adopted, may be of the same impurity or purity judged from a chemical analysis, but for all that the one will be a much better effluent than the other.

1201. How so?—The effluent from a chemical treatment of a sewage will have a much worse effect upon a river than the effluent by a biological treatment, whether through artificial filters or through land, and I would like to point out to you a case in my statement under the head of chemical precipitation. There is an effluent from Bradford Sandy Lane works, which gives oxygen absorbed in four hours 0·455, much under the working standard and the albuminoid ammonia 0·14, which is not greatly over the working standard, but that effluent is a very bad one notwithstanding. It is an effluent after alumino ferric precipitation in settling tanks only, and the Corporation of Bradford have, owing to the effect it had on the stream into which it was discharged since added filters.

1202. Of course, those making the tests should apply every test in doubtful cases, but for the rough apparatus of classification you agree with Mr. Scudder's tests?—I do agree with them.

1203. (*Colonel Harding.*) First, in regard to trade pol-

lutions, I see that in the area with which you have to deal there are nearly 1,300 separate cases of trade pollutions?—That is so, sir.

1204. Trade pollutions on the streams; therefore, you have, I suppose, a great variety of these pollutions?—I think there can be scarcely any trade in the country of which we have not a representative in the Riding.

1205. Therefore, your experience in a few years will be of great value to the country at large?—I hope so.

1206. Now you spoke about the willingness of manufacturers to carry out certain works, but I suppose if they are unwilling it is to a great extent due to the uncertainty as to what means they should take to purify their effluents?—I believe their unwillingness, when there is unwillingness, is due to two kinds of uncertainty; first, the uncertainty as to the state of the law, and, secondly, the uncertainty as to the means they should adopt.

1207. And, therefore, after you have had a larger experience of the work of your Board, probably their difficulties will rapidly disappear—They will lessen with every successful purification works that is constructed.

1208. The hesitation of local authorities to decide whether they will or will not admit trade effluents is largely due, I suppose, to the uncertainty of the expense to which they may be put if they have to deal with those trade effluents?—Very largely.

1209. In some cases the admixture of trade effluents with domestic sewage might involve totally distinct methods of treatment of the sewage of a local authority?—Yes. I might point to the case of Dewsbury, where they have a very successful farm on broad irrigation lines, and where at present only the domestic sewage is treated. If they were to take in all the trade refuse of the borough, they would certainly have quite to alter their method of treatment.

1210. In regard to many trade effluents, you think they are of a character that they could be admitted into sewers without seriously prejudicing the treatment of the sewage?—Certainly. I think that in all cases, however, the suspended solids should be taken out by the manufacturer before he discharges his refuse into the sewers.

1211. Therefore, while there are certain effluents which must be objectionable in regard to their reception into sewers, in most cases, where solids are deposited, you think that the effluents from manufactories might be admitted without objection into the sewers?—Yes, in most cases.

1212. Now, where that cannot be done, and where effluents must necessarily go into the stream, do you think it is sufficient for the present to call upon the manufacturer simply to deposit the solids?—No, sir; the Rivers Board has already, in its proceedings against a manufacturer, against a tanner, fought the question before the Courts on the matter of providing filtration, in addition to adequate settling tanks. The manufacturer was willing to provide sufficient settling tanks which would take the suspended solids out of his trade refuse, but the Rivers Board was not satisfied with that, and asked for an order compelling him to add filtration, and that he has done, or is doing now.

1213. And in such a case dealing with the effluent from a tannery, you probably might consider that the matters in solution were as objectionable, or might be more objectionable than the matter in suspension?—Well, in this case, in my evidence before the Court, I told the magistrate that the liquid matter discharged from the tannery was worse from the pollution of rivers point of view than ordinary town sewage, and that I strongly believe. It contains such a great deal of putrescible and putrefying organic matter.

1214. Then, where a trade effluent is turned into a stream, you think that, in addition to the settlement of the solids, there should in most cases be some method of filtration?—I think I would rather go further than that, and say that, in all cases, with very few exceptions indeed. There are some exceptions; for instance, the refuse from stone sawing, which we have at a great number of places in the Riding, need not be filtered, but, with some few exceptions like that, I think no satisfactory result will be got until means of filtration are adopted at all the manufactories.

1215. Then I understood you to say, in reply to a question, that a good deal of delay arose within your area in getting these trade pollutions stopped by the uncertainty as to the condition of the law in regard to the rights of the manufacturer to have his effluent taken into the sewers. There has been, I believe, no case actually brought before the courts except that one of Peebles *v.* the Oswaldtwistle Urban District Council?—I believe not, sir.

1216. Now, passing on to the treatment of sewage, I suppose the inefficiency of which you speak in connection with the treatment of sewage in county boroughs is due very largely, not only to the absence of suitable land, but to the great variety and volume of the trade effluents with which they have to deal?—Yes, they all take in a large amount of trade effluents.

1217. In regard to systems of precipitation only, have you formed any general opinion from your experience as to whether, by means of chemical precipitation only, satisfactory results can be obtained in dealing with the sewage of an authority receiving also trade effluents?—I do not know of any case where chemical precipitation and settlement is sufficient to give a good enough effluent to discharge into a stream.

1218. Then, have you formed any opinion as to the possibility of efficient treatment of sewage by chemical precipitation upon it by filtration through land in similar cases where there is the admixture of trade effluents?—Yes, I could point to Horbury, where a large volume of trade refuse is dealt with, where the combined sewage is chemically precipitated, and then dealt with upon land, and a very good result has always been obtained.

1219. Have you to deal in that case with the wool washings?—Yes, there is a good deal of wool-washing there and dye waters.

1220. Then how do you account for this: on page 34 of your tables I see in the case of the local authority of Ossett that chemical precipitation followed by filtration through land, seems to give somewhat unsatisfactory results?—The Ossett case is a peculiar one. In the Ossett district most of the mills, I believe, are working the shoddy trade, and in that trade, in addition to the ordinary dye waters and suds of the wool trade generally there is a vast amount of solids in the refuse from the mills, and of acid. There is a process in the shoddy trade by which the cotton in the old clothes, rags that are made into new goods, is destroyed by carbonising with acid, and very large quantities of acid are discharged in the mill refuse. Then in tearing up the old goods and in manufacturing them into new a great amount of fibre and dirt is discharged at various times with the trade refuse, so that the Ossett case is quite an exceptional one, and there the volume of trade waste is, I should say, many times the volume of domestic sewage.

1221. Then, passing to chemical precipitation and artificial filtration, the instance of Bradford appears to be specially interesting, is it not?—It is.

1222. In the case of Bradford, I suppose there is an immense volume of trade effluent consisting of greasy and soapy matters?—I should think there can be scarcely any worse sewage in the country than the Bradford sewage. It is the headquarters of the wool combing industry, and vast quantities of wool suds, with the grease of the wool, are discharged into the sewage, besides other trade refuse, and there the results are wonderfully satisfactory, considering the sewage dealt with. The method is simple precipitation by ferric sulphate, which is made at the sewage works from refuse procured from the gas works, and afterwards there is filtration through artificial filters, and you will see the results are rather over the working standard which has been suggested, 1·4 grains per gallon of oxygen absorbed in four hours, and ·17 of albuminoid ammonia, but, considering the sewage dealt with, I regard that as really wonderful.

1223. Then I notice that the effect of passing the effluent from precipitation in that case over coke breeze filters is considerably to improve it; as compared with the effluent from the precipitation, the effluent from the filters shows an improvement of about 50 per cent.?—Yes, it reduces the oxygen absorbed from 2·2 to 1·4, and the albuminoid ammonia from ·26 to ·17.

1224. I take it that these filters are not acting as mere mechanical strainers, but that they are intermittent filters, aerated filters, and that, to some extent, they treat biologically?—Yes, and I think, if I may say so, that the way in which they are worked might be very greatly improved. They are not worked quite on Dibdin's principles, although they are supposed to be filters somewhat on his lines.

1225. Well, now, passing to the Leeds experiments, I suppose we shall be able to get full details in regard to the Leeds experiments from the city engineer and from Mr. Dibdin, shall we not?—Yes; I should prefer that the information was laid before the Commission by the Leeds authorities.

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1226. But you give us, on page 35, the results of certain analyses which you have made in your laboratory, and I notice that in the second sample there is an improvement over the first sample, or, rather, the second average is an improvement on the first average?—Yes.

1227. And I understood you to say that that was due to the change which had been made in having two fillings a day in the second period, as compared with three fillings a day in the first period?—Yes, that is so, decidedly.

1228. But do you happen to remember whether the results of your analyses previous to the first average here referred to were not also improved on the earlier life of the filters?—The results have varied very greatly from time to time. At first, while the crude sewage was being treated on the filters, the average would be somewhat like the average for the April given in the table. Then for some time the effluent after chemical precipitation was treated, and an exceedingly good final effluent was obtained. Then afterwards the filling of the filter was carried out twice a day instead of three times, and the effluent again improved as compared with the effluent from the three times a day filling.

1229. Then the effect of three fillings a day with crude sewage at Leeds was gradually to silt up the beds?—Yes.

1230. They did not go on, did they, until the beds were absolutely silted up, but until the capacity had been considerably reduced?—Yes; it was found that the sludge was not being destroyed as it was added to the beds, and that, sooner or later, if the process went on, the beds would be silted up.

1231. Then a very interesting point arises: where a biological bed is silted up, will it be necessary to take out the material, and to refill the bed with entirely new material, or has your experience been that there is restoration by rest?—It has been the experience at Leeds on several occasions when the beds have been rested for a fortnight at a time, that a large amount of the sludge has disappeared in that time, and, I think, one very instructive fact was that, during this period of rest, the temperature towards the bottom of the filter was very much increased. The exact figures I should prefer that you got from the Leeds Authority; I believe it was 80° at the bottom of the filter, showing the rapid action that was going on in the destruction of the sludge, and the capacity of the filter. I should say that very careful measurements have been taken fortnightly of the capacity of these filters, and from these measurements it was known that the filters were becoming silted up when the crude sewage was put on, and it is also known that, after a rest of a fortnight occasionally, a greatly increased capacity was got,—speaking from memory, I think as much as 5,000 or 6,000 gallons in the fortnight in the filter, which is $\frac{1}{8}$ of an acre in extent.

1232. Then, so far as those experiments have gone, you think it likely that by rest the beds may be restored, and that, therefore, the destruction of sludge is a question of sufficient area of beds to permit some of them being allowed to rest the necessary time?—I believe it is so. I think, in the case of Leeds, a little mistake has been made in allowing all the crude sewage to go on containing road detritus and sand and cinders, which, of course, could not be dissolved by bacterial action, and that some, at least, of the silting up of the filter beds is due to that.

1233. Then you think in every case where crude sewage is put on biological beds, it is absolutely necessary first to have sedimentation of these mineral matters?—I should say so, or otherwise the beds will be in time silted up by fine sand or road detritus.

1234. I believe the Corporation of Leeds is at the present moment constructing several additional experimental filter beds similar to those which you have described to us?—Yes, for continuing their experiments.

1235. So that we are likely within the next few months to be able to get important results from those extended experiments?—Yes; and the experiments are being very carefully carried out at Leeds, with continual analyses and observations of atmospheric conditions, and of the capacity of the filters, so that they will be of extreme value, I am quite sure, when completed.

1236. And you have told us that there are other small authorities in the West Riding where experiments are being made on biological lines, but probably in those cases on account of the great expenditure necessary for constant analyses we shall not be able to get the scientific data necessary to enable us to judge?—I am afraid not; not to the same extent, at any rate.

1237. Now just a word with regard to these analyses. Is it not very important in comparing analyses to take into account the crude sewage of which the effluent is a result?—Very important. Since taking the analyses of sewage effluents I have tried to get average samples, and, as in those tables, you will see some of the samples are called "average crude sewage" and "average effluent." These average samples have been taken over three hours, in each case at intervals of twelve minutes. A Winchester quart is filled by taking a sample, an 8oz. bottleful of the crude sewage or of the effluent every ten minutes. That is for the purpose of being able to judge what results are being obtained. Of course, for the purposes of prosecution by the Rivers Board the worst sample would be the one that we should take—the worst that was being discharged into the stream.

1238. What I meant was this, that in comparing the results of land filtration we are comparing results very often of the treatment of mere domestic sewage, of very simple domestic sewage, with the results of the treatment of the most complex sewage of county boroughs?—Quite so, and in this table of sewage works where filtration through land has been adopted by far the majority of them are country places where there is only domestic sewage.

1239. The point I wanted to get at was this: Do you not think it is necessary where information is given as to the analysis of an effluent that information should also be given as to the analysis of the crude sewage from which it results?—Oh, quite necessary.

1240. The differences—for instance, at Bradford you have a crude sewage which you tell us can absorb in four hours twelve grains of oxygen per gallon, whereas ordinary domestic sewage I suppose would not exhaust much more than one grain?—No, sir; you see the others are about four.

1241. I will not venture in the presence of Professor Ramsay to ask you what your opinion is as to the proper basis of anlysis, but I suppose you think it very important that a basis should be settled, so that the results in different parts of the country should be comparable?—I would like to point to one thing in illustration of that. I have found in taking analyses of sewage emuents which were analysed by other chemists that the results did not agree, and on inquiring into it I found that, while it is our practice to analyse the sewage effluent as it is discharged to the stream, it was the practice of the other chemist to analyse the effluent after all the solid matters had deposited; that is, he analysed practically what would have been the filtered effluent filtered in the laboratory; we analyse the effluent as a whole. It is very necessary in comparing sewage analyses to know whether the one or the other course is followed. In that case we found that the amount of albuminoid ammonia was really nearly doubled by taking the whole effluent for analysis; if the effluent was filtered before analysis about half the amount of albuminoid ammonia was got.

1242. Then in addition to an uniform basis of analysis you think that we should take into account the character of the effluent as to future possible changes, and I understood you to say in answer to a question of my colleague that biological effluents were in your opinion likely to improve, whereas effluents from chemical precipitation were likely to deteriorate?—Certainly, in many cases after chemical precipitation, although the effluent when discharged is clear and bright, and looks very well, it has a very bad effect on the stream into which it is discharged. There is an after re-action takes place, and unless it is diluted with a very large volume of stream water the stream sometimes becomes exceedingly offensive. In the case of biological treatment, whether it is through land or through artificial filters, quite the opposite is the case, and one often finds in our polluted rivers that the part of the channel over which the effluent flows is cleaner and looks better than the rest of the channel of the river. I believe it is that the effluent after biological treatment carries with it a large amount of the germs which are still carrying on its purification.

1243. Then in estimating the amount of organic matter left in an effluent it would be unfair, would it, to take into account how much of the organic matter is living organic matter?—No. That is another thing that wants to be taken into consideration, because in the ordinary process of chemical analysis these living organic matters would be reckoned as organic matter generally, and would be included in the polluting organic matter.

1244. Whereas conceivably they might be elements of improvement?—Yes, quite so.

1245. (*Dr. Russell.*) I think you said you had nine district and assistant inspectors with definite districts. What qualifications do those persons have?—There are really

eight districts, and I have an assistant inspector at the office. These men have had very varied training beforehand. Five of them have been sanitary inspectors; one is from a borough surveyor's office, one had his training in an architect's office, and one has been an insepctor under the Fishery Board. The assistant inspector has been trained in our own office.

1246. And what is the general detail of the work they do for you; are they simply observers of what is going on?—That is so. They are supposed to observe and report weekly what is going on around them.

1247. So as to direct you when a personal inquiry may possibly be advisable?—Yes, and to take samples when samples are taken.

1248. With reference to this interesting biological experiment at Leeds, the marginal note says, "From sewage with trade refuse." I suppose the importance of that remark depends upon the nature of the trade refuse in Leeds. What is the general nature of the trade refuse?—Well, Leeds is one of the large towns, sir, that has all kinds of trade refuse. They say that a great deal of their good fortune depends upon having trade of all kinds in the town, but the two chief kinds of liquid trade refuse are from the woollen works and from the tanneries, with the addition of trade refuse from one particular chemical work which gives them great trouble in this biological treatment; it is an iron waste liquor.

1249. I suppose, in general, organic trade refuse would be more suitable for biological treatment than chemical?—Oh, certainly. I believe the worst kinds of trade refuse for either land treatment or other biological treatment will be the acid liquor discharged from dye-works very frequently, and this acid iron liquor.

1250. Acidity you think would be the element that would likely be most antagonistic to the life of the organisms?—I believe so.

1251. Would this biological method be capable of dealing with the contents of wool suds?—No; I believe that that is one of the kinds of trade refuse that cannot be dealt with by this new method, for this reason: the grease from wool suds is very difficult to destroy, and it would immediately clog up any artificial filters. It does clog up land very quickly.

1252. So that is an exception even to the general rule that organic refuse was most suitable to biological treatment?—That is so, but after the removal of the grease the remaining part of the wool suds can be very well dealt with on biological lines.

1253. You give us some very interesting examples of the abuse of storm water overflows, and you said that the Local Government Board in new schemes were very careful to take exception to methods which facilitated that abuse?—Yes.

1254. Would it not be of use to your Committee if they had power to make bye-laws as to the construction and working even of existing systems, following the precedent of the method of dealing by bye-law with trade processes which are likely to be offensive?—I believe it would be of very great service indeed. We do as it is get storm water overflows altered from time to time when we object to the way in which they are used, but we have only very indirect power to do so.

1255. You can do a great deal under those indirect powers by threatening proceedings upon the results?—Yes, that is so.

1256. Then you also mentioned some very extraordinary examples of schemes being sanctioned by the Local Government Board, and in the course of construction deviated from, and this not being discovered until some time afterwards accidentally?—Yes, that is often done, I am afraid.

1257. Have the Local Government Board no system of putting the authenticated plans of the scheme into the hands of somebody who will supervise the carrying of them out so as to see that the plans are followed?—No. I should like very much if the Rivers Board had a copy of any plans as sanctioned by the Local Government Board. We could then report to the Local Government Board whether the plans were adopted or not, but we have no means of knowing; we never see the plans which are sanctioned unless by the favour of the sanitary authority or of the engineer in charge.

1258. Well, however it is to be obviated, it is a very anomalous state of things to have a scheme the success of which depends on detailed structure, carried out without supervision and certification that it is carried out?—I think in my statement I mention two cases which were discovered just within a fortnight, where the plans, as sanctioned by the Local Government Board, had been materially deviated from, and the deviation was only discovered because a further inquiry for an extended scheme was proposed.

1259. I specially noted that illustration. Then, in instituting proceedings against pollution, you have dealt with trades as a whole, because you felt it was desirable, so far as your area was concerned, that trades of the same nature should be uniformly dealt with?—Yes.

1260. That, of course, applies equally to the whole country?—Oh, certainly.

1261. It would be desirable that persons following the same trades should be under the same rule so far as local circumstances varying would admit?—Certainly; and it is often a matter of complaint with the manufacturer that he has to go to the cost of putting down purification works while his neighbour in some other part of the country has none of that to do and has none of the extra cost.

1262. Then as to the admission of trade refuse into sewers where the manufacturer has not got room to deal with it. I think you would express approval of a special rate under those circumstances?—It is a suggestion really coming from the manufacturers themselves. There is a large association of manufacturers in the Colne and Holme valleys, a branch valley of the Calder. Huddersfield is in that valley, and perhaps two-thirds of the manufacturers in Huddersfield are allowed to discharge their trade waste into the sewers; the other third are refused permission to discharge their trade waste there. The manufacturers who are refused permission naturally feel that they have a grievance. In other parts of the valley there are at present no sewage works, but schemes are in hand, and the authorities are at present refusing to take trade waste into the sewers. It is felt by the manufacturers that their trade waste would be better dealt with by the sanitary authorities, and that, if in any case a manufacturer, for special reasons, could not drain into the sewers, he should be exceptionally dealt with, but that those who do drain into the sewers should pay something towards the extra cost of treatment of the sewage. That seems to me very reasonable, and in places where the manufacturers generally are not allowed to drain into the sewers—there are always exceptional cases, where perhaps the manufacturer cannot easily find room for purification, and if the river is to be purified, it will be necessary for the sanitary authority to allow him to drain into the sewer in such a case. If an exception is made in his favour, it is only reasonable that he should pay something towards the extra cost of ereatment.

1263. Yes, it seems equitable. Now, I have been trying to determine the *ultima ratio* of these Rivers Pollution Acts, especially with regard to the element of health. Of course, putting aside the dietetic use of water, and the injury produced when pollution goes the length of stinks, and such indirect methods of influencing human life as the use of water by domestic animals, there is hardly any other way in which polluted rivers can affect health?—I think those points you have mentioned include all the ways.

1264. Cover the whole ground, I think. As far as I can think it out, they do?—Excuse me, there is one other point which you have not mentioned, I think—the use of the water for manufacturing purposes, which is a very important thing in the West Riding.

1265. But how does that affect health?—Oh, it does not affect health.

1266. You have just gone in the direction that my next question applies to, because I see in the Acts references to "harmless"; the adjective "harmless" is used frequently both with reference to sewage pollution and manufacturing pollution. Now what comes within the scope of that adjective "harmless"—harmless with reference to what?—I am afraid, sir, those legal distinctions I must get you to ask a lawyer to define, but I think it is held by our Board—certainly I should personally hold—that no pollution would be harmless if it so affected the water of the stream that it could not be used for manufacturing purposes.

1267. Well, now, there is fish; does that come within the scope at all?—Certainly, although some of our streams are never likely to be turned into salmon rivers, there are others where the question of fish is a very important one. Those rivers to the North, the Ure, the Nidd, and the branches of the Ouse, are all good fishing streams, and we have constantly to take notice of pollutions, because complaints are made that they have been the cause of death to the fish.

1268. You probably would cover the whole area of hurt by those points of health, and by including fish and

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the use of of the water for manufacturing purposes?—I believe that is all.

1269. Of course, you work under a special Act, which differ from the general Acts, and has got some statutory powers which do not exist in the general Acts? Have you discovered any points in which you would suggest that there should be an extension of your powers even beyond the extension you already enjoy in your local Act?—There is one great point—I do not know if the Commission would deal with it—the question of solid refuse pollutions. We have just had a case appealed to the Queen's Bench, and a decision given against us where we took proceedings against a millowner for sludging his milldam into the stream. I believe it is the view of the Board—I certainly personally believe that to get efficient purification of the rivers we must be able to prohibit altogether the sludging of these milldams. Then another point that I have already mentioned to-day is that new pollutions are dealt with just in the same way as old pollutions. Now, new pollutions should be dealt with in a very summary way, I believe.

1270. (*Chairman.*) Was it held that he had a prescriptive right to sludge his milldam, or what?—It was quite a technical argument. The clause in our Act which prohibits sludging of mill dams is followed by a clause which says that "Any person who turns back into the stream anything which has come from the stream is not committing an offence if he does not pollute the stream or interfere with its flow, and the judgment was that he was turning back into the stream what had been brought to him.

1271. Brought to him from the stream?—Brought to him from the stream. We contended that it was polluting and obstructive, but the Judge held that it was not, being from a milldam in the very high reaches of the Don, where as nearly as possible it was natural silt carried down by the stream in the course of nature.

1272. (*Dr. Russell.*) Then, of course, there is that matter of the drainage from mines which you have mentioned?—That is another matter which was not dealt with in our Act.

1273. Have you seen the Bill that was introduced before the House this Session by Sir Francis Powell?—Yes, I have seen it.

1274. Have you read it and formed any opinion about it?—Well, I think in those particulars it does not go quite so far as our Bill. The question of dam sludging is not dealt with at all, I believe. And there is another point still I should like to mention, that in any new legislation the position of the manufacturers with regard to the sanitary authorities should be definitely set down once for all, and I should like to see a more easy course of legal proceedings in the case of manufacturing pollutions. At present it is a very tedious process.

1275. So that on the whole there is imminent need of a revisal of the Rivers' Pollution Acts?—Yes, I think so.

1276. (*Professor Ramsay.*) On page 34 of your long report I see that you estimate the ammonia albuminoid and free, and also the oxygen absorbed in four hours' treatment. That, I presume, as usual, means the amount of permanganate taken?—Yes.

1277. Is any attention paid to the nitrification?—Yes. I have just undertaken, in all those cases where average samples are taken as typical results of sewage treatment, to take the amount of nitrates, but in these that are before you nitrates were not taken.

1278. Have you begun this method recently?—Yes, quite recently.

1279. But you agree that it is a valuable guide, do you not?—Oh, very valuable, yes.

1280. Do you think it would be advisable to, if possible —I would like to ask you if you think it possible to judge of the decomposibility of water by finding the increase of nitrates, and the decrease of albuminoid ammonia?—Yes; it is for that purpose, I think, that the nitrates are valuable, the amount of nitrates present; it is a guide to how far the process of purification has gone on.

1281. And, I think, you stated in your reply to one of the other questions that certain waters which give apparently good results are really bad, because afterwards they pollute the stream, whereas others which give apparently worse results do not pollute the stream later on?—Yes.

1282. Then some such test as showing whether the water after keeping would develop nitrates would be a valuable aid?—Yes, it would be very valuable for that purpose.

1283. Another question which deals, I think, with page 35 is this: Does the efficiency of a filter increase with age; does it appear as if a colony of bacteria were increasing or gathering, so that, after some months' working, the filter is more efficient than it was at the commencement?—At the very commencement the filter is not efficient, but after it has been established for a short time—say, a month—the efficiency does not increase in all cases, it may diminish or increase according as the filter is overworked or not, but in ordinary circumstances it would remain as efficient after the first month. While you are referring to the artificial filtration, I think in all those methods of artificial filtration a great deal depends upon the weather, or, rather, the temperature, and the efficiency of the filters would depend very greatly upon whether the temperature is high or the temperature low. One reason for the results improving lately at Leeds may be that the temperature has been higher.

1284. I might just supplement this question, and ask: Would it be possible to get a large colony of bacteria by altering the rate of filtration, and so making the filter more efficient than it would be with a smaller colony? Have there not experiments been made to alter the rate at which the intermittent flow is kept up, with the object of developing colonies of bacteria?—I do not think I quite follow, sir.

1285. Well, it is clear that if you wash out your filter continuously, if you keep a large quantity of liquid running through, you probably put it into circumstances in which the bacteria are not likely to flourish. On the other hand, if there is very little water put through the same thing will happen, because there is very little food for them?—Oh, yes.

1286. Is it possible to hit a mean course where the filter will work its best?—It has really been with that view that at Leeds the number of times of filling the filter has been reduced from three times a day to twice a day. It was felt that better results might be got by giving the filter longer rest, so that the times of filling were reduced.

1287. So that some experiments of the kind have been made?—Yes.

1288. Then I want to ask about the possible disposal of manufacturing refuse. You say that in Yorkshire the general lie of the country is steep hillsides, with flat, rather narrow valleys?—Yes.

1289. Is it not possible to make use of the hillsides for storing purposes or depositing purposes?—Well, that is done, of course, in many cases. Advantage is taken of old quarries and waste land of that description for tipping refuse generally.

1290. Where it can be done?—Where it can be done, yes.

1291. I notice you speak of mismanagement of sewage works. "Where chemicals are used they are generally "added to the sewage quite by rule of thumb; precipita- "tion tanks are only attended to when they become filled "with sludge; and sewage is run on filters and on plots "of land until filters and soil become impervious and "sewage-sick." That, I fancy, refers to small places?—Yes, I say "especially in small districts."

1292. In the larger towns there is no such carelessness, I fancy?—Oh, there is much more care given to the sewage works. In these small districts sometimes the manager has other work to do, and only fills up his spare time by attending to the sewage works.

1293. I suppose the organic sludge, say, refuse from tanneries, or from wool works, ultimately disappers by fermentation?—From tanneries it would much more rapidly than from wool works; it would take a long time to destroy the grease from wool suds.

1294. Yes, but putting the grease out of the question—wool fibre?—Oh, yes; it would ultimately disappear.

1295. It would disappear quickly?—Not quickly, but it would ultimately disappear.

1296. Paper does?—Paper does comparatively quickly.

1297. And is anything known about the effect of making the effluent alkaline or acid with a view to cause one kind or another of the organic matters to disappear?—I do not know that any definite experiments have been made in that direction. This acid iron liquor which is discharged along with the domestic sewage at Leeds has certainly been found to interfere with the biological treatment of the sewage.

1298. Is it customary to recover soap; is it usual where wool scouring is resorted to to recover soap in the form of fatty acids?—I should think probably in about half the

cases; in a great many instances at present the wool combers discharge the refuse into the sewers in its crude state without recovering the fat. In Bradford, I believe, it is done.

1299. Do you know whether it pays or not?—Well, last year the Mayor of Bradford gave evidence before a Parliamentary Committee that the cost of putting down the plant and the cost of working was repaid, that he made five per cent. profit on the outlay and the working cost. But I should like to say that the method of working the suds plant in Yorkshire is of the very crudest, with one or two exceptions. The tank is allowed to fill with suds, and the man in charge empties a big carboy of acid into the tank without any measurement. And the filtration is done in quite as crude a way.

1300. I should have thought that when one man publicly announces that he finds it pay, other people would wish to imitate him?—No. You must look at it in this way, sir. It is a small detail of a large business; it is not worth their while attending to it properly, putting down a special plant and employing men to look after it when the profit is small; although there is some profit, it is not worth their attention.

1301. Can you tell me if any steps have been taken in any of the rivers—a long account of them comes at the end of your statement, page 54, and so on, where the trades are classified according to rivers; that is to say you put "coal washing"—"Aire," and "Calder," and so on—has any attempt been made under such circumstances to cause the manufacturers on the river to combine and arrange, if possible, to purify their own trade refuse? In many cases, a manufacturer turns out an acid for instance, as in iron pickling; in other cases he turns out practically an alkali in soap. Cannot these be brought together? Has any attempt been made to bring them together?—I think not, sir. The cost would be too great in laying drains to convey the one kind of refuse to mix with the other from different mills.

1302. I thought that would be your answer, yes?—In some instances, yes. I should say at the last meeting of the Manufacturing Pollutions Committee of the Board an attempt was made to get a body of manufacturers to combine whose mills all lie close together. Anyone of them would perhaps find some little difficulty in getting sufficient area for his purification works although they all have room, or can obtain room; but if they were to combine together there is plenty of room for a combined scheme, and the result in economy and in efficiency would be, I am sure, quite worth the labour. The Board tried to persuade those manufacturers—at least, did not try to persuade the manufacturers, but pressed them to consider whether a combined scheme could not be entered into.

1303. When a trade effluent is allowed to go into the public sewers, is the subsequent treatment efficient as a rule?—There are many sewage works where trade refuse is taken into the sewers which give a quite efficient purification. On the other hand, there are so many of the sewage works which would not be efficient for the domestic sewage even, that a general answer could not be given.

1304. But would it not be possible to make use of the sewers so as to run the various trade effluents down sewers to some common settling ground for the whole of the trade refuse to be treated altogether?—It was proposed in the Bill promoted by Bradford last year that all the wool combing refuse should be dealt with in that way, that special trade sewers should be constructed for taking all the wool suds to one centre, and there recovering the grease—afterwards treating the effluent after the recovery of the grease with the sewage of the borough, but that proposal was dropped in passing the Bill through Parliament.

1305. Was there objection on the part of the manufacturers?—I think the objection was the cost; a special rate was to be levied upon the manufacturers to pay for this trade sewer. If I am not mistaken, in Glasgow the Corporation has the power of making special trade sewers.

1306. Then, coming to my last point, viz., standards. You say that circumstances differ so widely in different cases that a fixed standard is impossible. Would you not allow yourself to be persuaded to take the position which was originally taken up by the alkali inspectors, to make a standard? There was a standard laid down by law which was regarded as ideal, but the alkali inspectors did not try to make the alkali works conform to that standard at once, but gradually put pressure on, so that, after ten or twenty years they do conform to it. Would it not be as well in this case to lay down some ideal standards which need not be hard pressed, which must be left very largely to the discretion of the inspectors?—Does it not then, sir, become not a fixed standard?

1307. Yes, quite true, but it becomes an ideal, which you can strive to attain, and which ultimately becomes a fixed standard. I suppose there is no alkali work which sends out anything like the amount of hydrochloric acid which is forbidden by the Act, but it has taken a long time to bring that on?—That is pretty much to do what we have done, I think—to have a working standard as a sort of test of purity or impurity of an effluent; some such standard as that, I think, must be adopted to enable one to judge of the impurity or purity, but further than that I do not think it is possible to go.

1308. The process of analysis is not so difficult but that in many of these chemical works someone might carry it out, so that the manufacturer might himself be aware whether he is exceeding it or not?—Oh, yes, in a chemical works especially, and in many of the other larger works in the wool trade, they have chemists, or men with a chemical training, there is no doubt. But I think the chief argument against a fixed standard, at least, in dealing with trade pollutions is this: "If you fix a standard sufficiently low, of course, it is not difficult for manufacturers to comply with it, but if you fix a standard sufficiently high, a manufacturer, who has his works in the country, with plenty of room available, can construct works which will bring his effluent within that standard. A manufacturer who has works in the town no doubt can construct the works—there is a possibility of his doing so, but it might cost him one hundred times more to construct the necessary works, and that would be a great injustice to him.

1309. But how would something of this kind do—to make standards of solid matter, suspended matter, and so on, high, because it appears to be easy to get rid of them, and to confine your other standards to what one may call putrescibility, so that no one shall drain into a stream stuff which shall subsequently deteriorate the water?—With a fixed chemical figure for it?

1310. With a fixed chemical figure for it, if it were possible to fix such a figure?—I do not think, sir, you would find it possible. I should be glad if there were a fixed standard for the manufacturers to work by, but I do not think it is possible. You would either make it too low, and prevent yourselves getting sufficient purification in the country districts, or you would make it too high, so that the men in the town districts could not conform to it.

1311. (*Major General Carey.*) Then, would there be any difficulty in making some kind of standard in the case of sewage effluent, a high standard for solid and suspended matter, and a low standard for putrescibility?—There would not be the same difficulty in making the standard, but I feel perfectly strongly that, in the case of sewage effluents, it is not necessary to have a fixed standard, that you should not expect the same amount of purification in all cases, that in the case of an effluent being discharged into a large stream, where it is many times diluted, you do not require the same amount of purification as you should require when the effluent is discharged into a small stream. In many of the rural districts the water of the stream below is used for drinking purposes; you must necessarily get from authorities there a greater amount of purification of their sewage than from an authority low down the stream where the water is not used afterwards except for manufacturing or navigation.

1312. Under the head of causes of failure of sewage works: "Even when very complete schemes of sewage "disposal have been constructed, the efficient treatment "of the sewage is often prevented, because the sanitary "authority, from motives of false economy, puts the "works under the charge of quite an ignorant working "man," so that they have neglected the work. That applies in a greater degree in the case of bacteria filters themselves when this process comes into general use?—It does.

1313. And that has to be taken into account as a very important factor in judging of the value of this process for general application?—Yes, certainly, mismanagement of these bacteria filters——

1314. Would be very injurious indeed?—Yes, very serious.

1315. And, I put the question yesterday, in the case where precipitation and land filtration is adopted as against either artificial filtration or bacteria treatment, the neglect in the cases of bacteria treatment would probably produce a worse effluent than in the former—than in the land treatment?—Yes, in the case of land, the land would be spoilt.

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1316. Yes?—In the case of artificial filtration not only would the filter be spoilt, but the effluent would come through unpurified.

1317. And the filter would be absolutely unworkable until the material had been renewed or cleansed?—Yes, or until it had had a sufficient period of rest for recovering itself.

1318. With regard to your table, you have not the results of the sewage treatment of these different places?—I did not like to put down definite results in all those cases, because, as I have said, the laboratory has only been in operation for nine months, and we have not chemical results, but I can give you the general results from inspection and not based on chemical data if that is any good—the results judging from the effects.

1319. From the appearance of the effluents, you mean?—Yes, and the effects on the stream. But it is not a scientific thing in any way; I do not think it is much good.

1320. No. With regard to the treatment of sewage on clay land, you say that it has been absolutely rejected—that clay land has been rejected as totally unsuitable in the West Riding for sewage disposal?—No, sir. Perhaps I may refer to Eccleshill.

1321. Yes. "The authority, therefore, is in the unfortunate position of having spent £26,000 upon works "for sewage disposal, the rateable value of the district "being under £25,000, and is yet no nearer the effective "purification of its sewage. And, again, at Hebden "Bridge, the works of sewage disposal were sanctioned in "1897 by the Local Government Board; those works "include the treatment of sewage by chemical precipitation upon some acres of land, the subsoil of which at a "foot deep is stiff and wholly impervious clay." This is apparently a failure?—That is a scheme in progress, sir.

1322. Yes, quite so. The first, Eccleshill, is apparently a scheme of broad irrigation?—Yes.

1323. The statement that the treatment is absolutely ineffective, and must be so because it is clay land, does not quite agree with the conclusions of the Royal Commission of 1868. They conducted a series of experiments, and one, which I have casually looked up, is Norwood, and in putting a series of results of analyses of the effluents, they say, "These results, extending over an "entire year, show that the effluent sewage was, except "in a few instances, so far cleansed, even upon this heavy "clay soil, as to be admissible into running water without "nuisance." And, I think, in other cases they have, so far from rejecting clay land as unsuitable—they look upon it as not as good as the other, but as land which could produce certain satisfactory results if properly managed?—I think, sir, as land generally varies, so clay soil varies. The clay soil that we meet with in the West Riding is, I know, so absolutely impervious to water that water will stand in it until it evaporates. There are other clay soils which do absorb water to a certain extent, do allow water to pass through, but such stiff boulder clay as we get in the West Riding will not let water pass through it.

1324. Then we will pass to the storm overflows. Has the proportion of the dilution of sewage with storm water been considered in the West Riding before a storm overflow comes into operation?—Nothing has been definitely fixed by the Rivers Board, but, as a rule, at Local Government Board inquiries of late, at least, the storm water overflows have been fixed at such a height that they only come into action when seven times the ordinary average daily flow of sewage is passing. But that is not in order to conform with any fixed standard; it is a matter of agreement really between the sanitary authority and the Local Government Board, often because a representation has been made by the Rivers Board at the inquiry.

1325. Has the Rivers Board any opinion that the proportion is sufficient or satisfactory?—No, sir; the Board has not expressed any opinion.

1326. Personally, have you any opinion on the subject?—Well, as far as I dare give an opinion upon a purely engineering question, I think this is a very reasonable requirement, that no storm overflow should begin to act until seven times the ordinary daily flow is passing. I may say that some of the authorities would like to have their storm overflows allowed to act when three times the average daily flow—they have even mentioned twice the average daily flow—is passing. But that is a flow which occurs practically daily; the maximum flow, I should say, is often three times the average daily flow.

1327. And the first flow after a storm, I suppose—the first flow from the streets is exceedingly polluted?—Yes, worse than the ordinary sewage.

1328. Worse than the ordinary sewage?—Yes.

1329. Have any proposals been made for the disposal of sludge which usually lies in heaps beside the works; have any attempts been made in the West Riding to press the sludge?—Yes.

1330. To pack and sell and dispose of it?—In several cases. In the case of Huddersfield they have sludge presses, and those, I believe, they are now using; they only lately began to use them afresh. In the case of Bradford, I know that in connection with their new scheme they are considering the purchase of sludge presses, and have been to visit various places where sludge presses are in use. But they are not the rule in the Riding.

1331. And, of course, if the sludge is not pressed, and if it is kept in heaps near the works, it really creates a most tremendous nuisance?—Yes, sometimes a very serious nuisance. The difficulty really is that, even after it is pressed, they cannot get rid of it.

1332. They cannot sell it?—They cannot sell it.

1333. The farmers will not take it?—No, as a rule, not. In some cases, in the smaller districts and in the rural districts, they do get rid of it to the farmers, but in the populous parts on the Aire and Calder, the farmers will not take it, or only take it very irregularly, and at certain times of the year.

1334. With regard to the admission of trade refuse into the sewers of a district, in the case of Otley and Burley you say, "The soil of the sewage farm is deep alluvium, "specially suitable for purification of sewage, and these "and other similar instances, go to prove that land treatment is not adapted for the disposal of sewage mixed "with trade wastes, unless by previous chemical treatment the deleterious matters are removed from the "sewage." Of course, under such circumstances, it becomes exceedingly difficult for a sanitary authority to consent to the admission of trade refuse into their system of sewers unless they can have a moderate certainty of being able to deal with it. Their scheme may be ruined after having spent a very large sum over it; their whole scheme may be ruined—by the admission of this trade refuse into their sewers?—Quite so, yes; there is, of course, a large number of authorities in the Riding at present who are considering larger schemes of sewage disposal or improvement schemes of present works. In those cases it is open to them to state definitely whether they have this trade refuse to deal with or not, and if they are going to deal with it, then to make their works accordingly large.

1335. But, I suppose, even then it would not be at all a certainty that they could deal with it, however large, unless it was conducted separately to the works, and then treated with the sewage effluent?—I think, if some such preliminary conditions as are imposed in the case of Keighley were imposed upon all manufacturers before they discharged their refuse into the sewers, there would be no difficulty in dealing with the mixture.

1336. No matter what kind the refuse was?—With the one exception, that acid effluents might interfere with any biological treatment, it would not be difficult to deal with the combined sewage, if some form of chemical treatment was adopted, followed by filtration, because the chemicals could be adapted to deal with anything objectionable in the mixed sewage.

1337. And, I understand, that at Leeds in those experiments that have been made with biological filters, that sewage is mixed with trade refuse; it is not a domestic sewage?—No; there is a large amount of trade refuse mixed with it.

1338. Trade refuse of different kinds?—Of all kinds.

1339. And you say, with satisfactory results as far as you know?—Yes. I should say the results were satisfactory; they just barely conform to that working standard, but they are generally just about that mark. I should be, I think, quite contented if the whole of the sewage of Leeds were turned out in the same state of purity. I should perhaps say, that in the effluent—in this crude effluent from Leeds that is unmixed with any river water, fish have been kept for the last six months, the same fish have lived for the last six months, and some of them, at least, are fat and well to-day.

1340. That is in the effluent?—That is in the effluent alone.

1341. In the bacterial filter?—In the effluent alone, without any dilution, even although at times the effluent

contains more suspended solids than we would like. I believe that a great deal of the suspended solids in the effluent at Leeds is due to this acid iron liquor. The iron seems to pass through the filters, and become precipitated afterwards in that effluent after oxidation.

1342. (*Sir Richard Thorne.*) I had not the advantage, Dr. Wilson, of hearing your evidence in chief to-day, so that I am not able to ask many questions, and I may possibly ask you some that you have already answered. May I ask you whether your opinion as to the failure of broad irrigation in your water board area is mainly due to the quality of the land or to the trade refuse which is mixed with the sewage?—As a rule, broad irrigation is fairly successful in the Riding, because it has usually been adopted in quite rural districts, where the refuse is purely domestic. In the places where it has failed, it has been due chiefly to the nature of the land.

1343. Now, speaking quite generally, and excluding for the moment the acid refuse from the iron works, could you mention any one system of sewage disposal which, in your opinion, is best calculated to deal with combined domestic sewage and trade refuse?—I think the best system for such trade refuse is one in which chemical precipitation is followed by land filtration if the land is suitable and of sufficient area, because, by the chemical precipitation, you can get rid of any deleterious matter which would interfere with the treatment of the effluent through the land, but by that treatment you still have the sludge difficulty to contend with.

1344. Then is there any one of the systems which is, in your opinion, less adapted to deal with trade refuse when combined with domestic sewage than another?—Well, I am strongly of the opinion that land treatment alone is not suited for dealing with combined sewage of that kind, unless at the mills all the deleterious matter has been taken out, as is the case, for instance, at Keighley.

1345. Now, with regard to the septic process and biological filters, have you at all thought of the question as to the opportunities which might be afforded in them for the multiplication of specific microbes, which would then go out in increased abundance with the effluent?—That is a question, I think, that wants to be decided before these systems are generally adopted.

1346. You have no opinion upon it yourself?—No; I have no evidence to offer upon that.

1347. I suppose you would accept the view that the cholera organism, for instance, is fairly soon drowned out in water or sewage, but if it can get the advantage of floating in a river on a minute portion of organic matter the means of its livelihood are afforded to it, and it multiplies?—Yes, certainly.

1348. Now, do those conditions in any way correspond with those obtained in the biological filter?—If the immense number of other germs in the biological filter did not kill the cholera organisms, there would be the opportunity for them passing through the filter; there is nothing to prevent them; a filter is not so fine in its pores as to prevent any disease germs passing through it.

1349. Of course not; but I was rather thinking of the opportunity of multiplication which this organism might get, which might enable it to over-ride opposing organisms by means of the amount which it has attained?—I think that is one question that wants to be decided—whether the opposing organisms would not altogether destroy the disease germs.

1350. You made a remark as to the relation of sanitary authorities to manufacturers needing revision. Had that reference to the admission into the public sewers of trade refuse?—Yes.

1351. May I take it that, if the biological filter method increases, there would have to be still greater severity exercised as regards the admission of trade refuse into sewers than before?—No, sir, I do not think so, if sufficient conditions were laid down by the sanitary authority for the treatment of the trade refuse before it is admitted to the sewers.

1352. Then you think that there will necessarily have to be some chemical treatment?—No chemical treatment in the case of some kinds of trade refuse; certainly, in the case of the wool suds I have mentioned chemical treatment is necessary to remove the grease; in the case of tanyard refuse no chemical treatment will be necessary.

1353. No, I suppose not?—In the case of any very acid effluent, probably some form of treatment for neutralising acid would be necessary.

1354. Then you think that the adoption of biological methods would not really increase that difficulty at all?—I do not think so under proper precautions.

1355. Now you were asked a question by Dr. Russell which bore upon the supervision of local authorities to see whether they carried out their systems of sewage disposal according to the terms on which they received their loans, and which bore also upon the future management of those schemes?—Yes.

1356. I should like to ask you, can you conceive of any system under which that could be carried out by the central authority, say, the Local Government Board of this country?—No, unless the inspectors were to yearly or periodically visit all those sewage works, it could not be done.

1357. Even a yearly visit would be a very, very occasional surprise visit, I suppose?—Yes.

1358. Nothing more?—Nothing more.

1359. Would that really do much towards securing a proper method of sewage disposal?—It would not secure the management of sewage works, but it would secure that the schemes as sanctioned by the Local Government Board were carried out.

1360. It might do that?—And that is really what is wanted. The supervision of the sewage works after they are constructed may, I think, safely be left to the local authorities, but they are not able, for want of information, to see that the scheme as sanctioned by the central authority is carried out.

1361. But I suppose that if, for example, a Board like yours knew what schemes had been sanctioned, and the terms of those schemes, the supervision you refer to could very much better be carried out locally than even by a central authority, could it not?—I should not like to speak definitely as to that. What I had in my mind was that the Rivers Board would communicate with the local authority that their scheme as sanctioned had not been carried out, and that if we found the sanitary authority, because they have not carried out this scheme, still polluting the river, then we would have good grounds for taking proceedings against them, and it would be strong evidence in our favour.

1362. But, apart from that, what could the Local Government Board do?—Well, I believe, sir, the only thing they can do is to refuse future loans.

1363. Quite so; but they can do that without making the annual visit, because, when the Inspector goes down about the new loan, he would generally see that the former scheme has not been properly carried out?—Perhaps that is the only way in which they can act.

1364. I have only one other question to ask you, and it relates to standards. I am very much impressed by the fact that all the scientific experts we have had before us have objected to standards, and yet, like yourself, they have all adopted standards. Can you explain the apparent anomaly in any way?—Well, sir, it is quite necessary, if you are going to express any opinion at all as to the purity or impurity of an effluent, you must have some kind of standard to judge it by, but it need not be a legal standard to which every effluent must conform.

1365. No, but does not your standard become a legal standard from this point of view, that you only take proceedings against people on the basis of the standard that you have decided to adopt?—Yes, but that is a very different thing from having a legally adopted standard. Supposing in every case where a sanitary authority did not turn out the effluent from its sewage works in conformity with our working standard, they were thereby committing a legal offence, that would be a very different matter from our opinion only, that they were polluting a stream because they did not conform to the standard which we have adopted as a working standard. The legal adoption of the standard makes all the difference.

1366. The point really is that your Board do not act adversely to any interests unless a certain standard is exceeded; therefore there is no action to prevent the pollution of a stream unless a certain standard which you and others have adopted is passed. Is that not so?—I do not say even that. In the case of the Bradford Sandy Lane sewage works, although that effluent practically conforms to this working standard, we should have put pressure upon the authority to improve their sewage works had they not done so of their own accord, because the effluent was causing marked pollution in the stream even although at the time—twice I believe we have taken samples of the effluent—we have found it conforming to this standard or nearly so.

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1367. (*Professor Ramsay.*) But is not that an argument in favour of a different kind of standard, the one I was suggesting, which takes account of subsequent putrefaction?—Oh, I strongly believe that if you are going to have a standard it cannot be a standard based only upon the albuminoid ammonia and the oxygen absorbed; it must be a standard showing the amount of purification as judged from the nitrates, and especially the effect of the effluent upon the stream.

1368. (*Mr. Killick.*) I suppose it is the case that if you decide to prosecute an authority or a manufacturer you take other analyses besides the oxygen absorbed and the albuminoid ammonia?—Oh, yes.

1369. And that is the case also in the watershed of the Mersey and Irwell?—Yes.

1370. These so-called standards are notes for classication of the effluents?—It is impossible in all the analyses we take to go through a complete analysis of the effluents, and we take those as being the best guide to the fact of pollution or not.

1371. If you came to the Court you would have the analyses mentioned by Professor Ramsay also taken?—Yes.

1372. (*Sir Richard Thorne.*) How many years did Dr. Whitelegge hold the position that you hold in the West Riding district with regard to rivers?—He of course was appointed medical officer of the County Council, I should think, in 1889; it was very soon after the constitution of the County Council.

1373. Did he not at once begin taking up the question of river pollution?—Yes, very shortly.

1374. Should I be right in assuming that in all probability he has information that might be useful to this Commission although he is no longer officially connected with the Board?—I am sure he has; he has, if anyone has, information as to the state of matters when the County Councils were constituted in the West Riding.

FIFTH DAY.

Wednesday, 27th July, 1898.

PRESENT:

The Earl of IDDESLEIGH *Chairman, presiding).*

Sir RICHARD THORNE THORNE, K.C.B., F.R.S
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS (*Secretary*).

Dr. THEODORE THOMSON, M.D., Medical Inspector under the Local Government Board, called; and Examined.

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1375. (*Chairman.*) Dr. Thomson, you are, I think, an inspector of the Local Government Board?—Yes.

1376. You have made inquiry on behalf of the Local Government Board as to the "Septic tank" system of sewage disposal at Exeter?—Yes, in association with General Crozier, on two occasions; first, informally, on May 26th and 27th, 1897; and again, formally, on November 23rd to 27th, 1897.

1377. The system had been in operation in experimental form, had it not, for some time prior to your first visit?—Experiment was begun on a small scale on April 5th, 1895, and continued throughout that year. Larger works were resorted to in January, 1896; and on July 21st, 1896, still larger works were brought into use. These last were the works into whose working I make investigation; they had continued in use, I was informed, without intermission up to the dates of my inquiries.

1378. What portion of the Exeter sewage was dealt with in these works?—They dealt with the sewage of the St. Leonard's district of Exeter, with a population estimated at about 1,500 persons. There are no manufactories in this part of Exeter, so that the sewage is entirely of a domestic character. The sewer from the St. Leonard's district is 18 inches in diameter, and its daily flow after a period of drought in 1896 was found to be 35,000 gallons, the variations in flow being from 81,000 gallons at 10.30 a.m. to 500 gallons at midnight. Sewage from this sewer was conveyed to the experimental works by a 6in. pipe, 134 yards long, a temporary weir being placed across the St. Leonard's sewer just below the point at which this 6in. pipe left it. The maximum amount of sewage flowing through this 6in. pipe has been gauged at 122,000 gallons in 24 hours; and when sewage was passing along the St. Leonard's sewer in excess of what the 6in. pipe could take, this surplus sewage passed over the weir in the sewer and was discharged at the St. Leonard's outfall into the river Exe. The average amount of sewage treated at the experimental works up to my first visit, in May, 1897, had been 55,000 gallons per day.

1379. Will you describe the works?—The works consist of a tank, termed the "septic tank," and five filter beds. The tank is built of cement concrete, and is arched over. It is 64ft. 10in. long and 18ft. wide, with a capacity of 53,800 gallons. At the end where sewage enters there are two "grit chambers" divided off from the rest of the tank by a partition wall. The sewage enters one or other of these two grit chambers by a 6in. pipe at a point about 5ft. from the bottom of the chamber. Each grit chamber is 8ft. 6in. by 7ft., and is 10ft. deep from the water line. In the roof of each grit chamber there is a manhole with an air tight cover through which the chamber can be cleaned out. From the grit chamber sewage flows over the dividing wall into the other and main portion of the tank. This main portion of the tank has a depth of 7ft. to 7ft. 9ins. from the water line. In its roof are a manhole with an air-tight cover, and smaller holes, ordinarily kept closed, for the taking of samples of the tank contents. There is also an inspection chamber about the centre of the tank, from which the interior of the tank may be observed. The outlet from the tank is at the opposite end from the grit-chambers, and consists of an iron pipe 16½ins. below the water line. From this outlet the effluent from the tank flows into a gauge chamber; thence to an iron trough termed the "aerator," over the sides of which it falls into channels conveying it to distributing chambers, whence it passes to one or other of the filter beds. Each filter bed has a superficial area of eighty square yards, and is 5ft. deep. At the bottom 3in. agricultural tile drains are laid, surrounded by a 6in. layer of river ballast. In four of the five filters 4ft. 6in. of furnace clinker, broken to a size to pass a ½in. sieve, and be retained by a ¼in. sieve, is laid on top of the ballast; in the fifth filter 4ft. 6in. of coke-breeze, of rather coarser size, is employed. The original capacity of each filter is about 11,000 gallons. With dry weather flow, each filter bed takes, it is estimated, about four hours to fill, but during wet weather, when the flow from the septic tank is greater, this may be considerably reduced. Each filter, after being filled, stands full during the time it takes to fill the one to which the tank effluent has been diverted from it: a period, therefore, during dry weather flow, of about four hours. As soon as its successor is full it begins to discharge; and it is not again brought into use until the third and fourth filters have, in their turn, been filled. Only four filters are used at

the same time; the fifth standing out. So that in dry weather a filter bed is filling during four hours; remains full during four hours; and rests eight hours. When a filter bed is discharging its contents, about 60 per cent. of the whole amount, it is estimated, passes out in the first twenty minutes; the flow decreasing rapidly as it empties. There is a slow dribble from the filter, however, long after the bulk of the contents has been discharged.

1380. Will you tell us how it is claimed that purification of sewage is brought about in these works?—It is claimed that two different processes take place in the septic tank and in the filter beds respectively, both tending to purification of the sewage. The sewage, in the first instance, enters one of the grit-tanks, and there such heavy material as road-detritus sinks to the bottom of the chamber. On the occasion of my visit in May, 1897, the depth of deposit in both these grit-chambers was about 21 inches; in November it was 17 inches in one of the grit-chambers, and 24 inches in the other. From the grit-chamber the sewage passes into the remaining and chief portion of the tank. On inspection the contents of the tank may be observed to consist of a scum, lying on the surface, some three or four inches thick, and composed of black material with an offensive odour. Below this scum comes a layer of liquid, several feet in depth, containing a good deal of matter in suspension. Beneath this comes a layer of black matter covering the bottom of the tank. This layer in May, 1897, ranged from ten to thirteen inches in depth; while in November it averaged about twenty-three inches in depth.

1381. May I just ask you then, do you know for how long it had been in use before May, 1897?—It was sixteen months up to November; ten months up to May.

1382. In the first ten months it accumulated from ten inches to thirteen inches, and in the following six months—did you say, sixteen months up to November?—Sixteen months up to November.

1383. So that in the first ten months it accumulated from 10in. to 13in., and in the next six months about 10in. more?—Yes; that is so. It was stated at the inquiry in November that the tank had not been cleaned out at any time since its coming into use. In the space between the surface of the tank contents and the arched roof gases accumulate. This is shown by the removal of a cap from a wire-covered pipe communicating with this space and applying a light to the outer extremity of the pipe, the issuing gases burning with a pale blue flame. The changes which are brought about by sojourn of sewage in the tank are said to consist mainly of conversion of part of the solids in suspension into solids in solution, and of the breaking down of complex organic compounds into simpler compounds. As a result of changes in the tank, the sludge difficulty is, it is claimed, got rid of, since the necessity for precipitation of suspended solids is avoided; and the offensive matters in sewage are brought into a condition that renders them more easily dealt with in the next stage of the process. These changes are attributed to the action, mainly, of what are known as "anaerobic" micro-organisms—micro-organisms, that is to say, that need no atmospheric oxygen, and that find, accordingly, a suitable medium in the "septic tank," to which very little oxygen is believed to gain access. The evidence brought forward at the formal inquiry regarding the action of the tank consisted mainly of chemical analyses of the composition of the effluent from the septic tank; of bacteriological examinations of the tank contents and tank effluent, and of comparison of the amount of solids that had accumulated in the tank with the amount that had entered in the sewage, the proportion of the former to the latter being estimated as small. The effluent that leaves the tank is passed through one of the filter beds, and the main changes that then take place are stated to consist of decrease of solids in solution, decrease of organic matter, and the formation of harmless mineral compounds in the form of nitrates. These changes are attributed to the action of micro-organisms in the filter beds; but these organisms, unlike those in the septic tank, need atmospheric oxygen, and are therefore known as aerobes.

1384. Will you describe the sort of effluent obtained by treatment of sewage in the "septic tank" and in the filter beds?—The effluent from the septic tank contains in suspension a considerable amount of finely-divided black matter, and emits a distinct odour of an offensive character. The chemical evidence at the public inquiry was to the effect that purification of the sewage had occurred in the tank in a degree varying from 25 to 63 per cent., judging by amount of oxygen absorbed, and of 17 to 55 per cent., judging by reduction in the amount of albuminoid ammonia. The effluent from the filter beds varies in appearance and character according to the length of time after the filter has begun to discharge. Samples taken when the filter is discharging rapidly usually have a slightly opalescent tint and a faintly unpleasant smell on shaking; samples taken when the effluent has become a dribble are quite clear and emit no smell. The chemical evidence at the inquiry was to the effect that the effluent from the filter beds had, as compared with the raw sewage, undergone purification to an extent varying from 81 to 88 per cent., judging by amount of oxygen consumed, and of 63 to 77 per cent., judging by reduction in the amount of albuminoid ammonia. The bacteriological evidence at the inquiry showed that the number of micro-organisms present in both the tank effluent and in the effluent from the filter beds was very great.

1385. I suppose you did not make any experiments yourself?—None whatever.

1386. You simply accepted the view which was put before you?—Quite; I accepted the facts.

1387. Did these experimental works give rise to any nuisance?—No evidence was given at the public inquiry that nuisance had been caused by the experimental works; and the Medical Officer of Health for the City of Exeter stated that he had never received any complaint as to nuisance created by them. I myself, in November, 1897, noticed an offensive smell from one of the filter beds; this, however, was not sufficiently marked to be noticeable at a distance of more than 20 feet. On the surface of this particular filter bed a slimy scum was visible; and the City Surveyor informed me that the surface of the filter had not been raked over for several months, but had been left undisturbed.

1388. Was that particular filter in work at the time?—It was.

1389. And the scum did not prevent the stuff penetrating?—Apparently not.

1390. As result of your inquiry what opinion did you form as to the applicability of the "septic tank" system to the treatment of the sewage of the whole City of Exeter?—I came to the conclusion that, while a considerable degree of purification of the City sewage might be looked for by this process, yet it was desirable that the effluent produced by it should be submitted to further purification by treatment on land before discharge into the River Exe.

1391. Will you tell us the grounds on which you arrived at this conclusion?—The main considerations by which I was guided were as follows:—(1) While in many instances the chemical analyses that had been made of the final effluent produced by the Exeter process showed that a great deal of purification had been effected, yet in many others the results thus indicated were less satisfactory. In several the actual amounts of organic nitrogen or of albuminoid ammonia were, in my judgment, too high to permit the effluent being regarded as satisfactory. The variations in amounts of ammonias in the effluent, and the differences in degree of conversion of organic matter into nitrates, were shown to be very considerable; nor did it appear clearly to what those variations were to be attributed. Neither was I satisfied that the large numbers of micro-organisms in the final effluent constitute, as was contended at the inquiry, a favourable indication. It is open to question whether this condition may not be held as tending to show that a good deal of matter requiring oxidation still remains in the effluent; and the want of knowledge as to the precise nature of these organisms leaves room for doubt as to whether some of them at least may be of a sort not desirable in an effluent. (2) I was also not satisfied with the evidence regarding possible influence of heavy rainfall on this process of treating sewage. The value of the information given on this point was much lessened owing to the fact that the 6in. pipe leading to the experimental works was not large enough to take all the flow of the St. Leonards sewer during heavy rainfall; and, accordingly, there was not sufficient evidence, based on actual experience, as to the effect of heavy rainfall on the process. This influence may be regarded in three ways:—(*a*) During heavy rainfall the stay of sewage in the "septic tank" is necessarily shorter, and, to a corresponding extent, the sum of the action taking place in the tank cannot but be less. The movement of sewage in the tank might be affected also by heavy rainfall in such a way that instead of incoming sewage pushing the previous contents of the tank before it, the sewage might displace part of these laterally and stream through the tank, in which its stay might thus be very short indeed. Evidence was given on this point at the inquiry, but this evidence was based on experiments made during dry weather. (*b*) As was contended at the inquiry, the

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condition of great dilution of the contents of the tank produced by heavy rainfall would tend to changes taking place less actively. (c) Heavy rainfall might exert a prejudicial influence on the action of the tank by washing away a large proportion of the micro-organisms that bring about the changes that take place in the sewage while in the tank. On all these points regarding possible influence of heavy rainfall the amount and nature of the evidence given at the inquiry was insufficient to justify definite conclusion. (3) The evidence as to the influence of season, more especially of severe cold, on the action of the Exeter process was not sufficiently ample to afford means of judging how it would be affected by these conditions.

1392. In case of any proposal to apply this system of sewage-treatment to other places than Exeter, would you have any remarks to offer in addition to those you have already made?—Yes. It would be necessary to consider the quality of the sewage to be treated. The experimental works at Exeter dealt only with domestic sewage, into which no manufacturing refuse entered. In the case of a town of which the sewage contained manufacturing refuse it would be necessary to consider the nature and proportion of these trade effluents in the sewage; inasmuch as these effluents might check the growth and life-processes of the micro-organisms to which the modifications brought about in sewage by this process are attributed. This question arose at Exeter, where there are two paper-works, two breweries, one tannery, and one soap and candle works. It was shown at the inquiry, however, that the refuse entering the sewers from those works was not of a quantity and character that would be likely to affect injuriously the "septic tank" system of sewage treatment. It would be advisable also to consider the size and character of the stream into which the effluent from the sewage works would discharge; the purpose to which the stream is put as regards fisheries of one or another sort; and whether or not the water of the stream would be likely to be used for drinking purposes. At Exeter it is proposed that the effluent from the sewage works after treatment on land shall discharge into the river Exe; a river of considerable size, which is semi-tidal at the point where the effluent would be discharged into it, and which would not, below that point, be used for drinking purposes. If the stream were to be used subsequently for drinking purposes it would be a matter of importance to ascertain whether organisms capable of causing disease could pass through the tank and filter beds and reach the stream in a condition that would permit them doing injury to health. At the inquiry at Exeter some evidence was given on his point; but the conditions of the experiment on which the evidence was based differed too much from those of the Exeter process to warrant definite inference as to what would happen in the actual working of the process.

1393. Then to take that last paragraph, you would form no opinion whatever about the possibility of disease germs getting through the artificial filter?—The evidence given at the inquiry went to show that these germs could get through both tank and filter, but in very small proportion.

1394. The evidence did go to show that they could get through?—It did.

1395. Yes?—But I was not satisfied with the conditions under which the experiments were conducted. In one respect I think, perhaps, they were too favourable to the process; in another respect they were, perhaps, unfavourable to the process. In the first place, the enteric fever organisms, which were those which were employed, were kept in sterilised sewage for a period of forty hours, that being supposed to represent the action of the tank. I do not think that we can say that that does represent the action of the tank, which is a thing we at present know very little about. And, in the second place, the organisms were kept there for forty hours. But during a heavy rainfall the stay of the sewage in a tank of the size which was used in the experimental works would be nothing like forty hours.

1396. No?—It would be six or seven hours probably at the very most, and therefore this part of the experiment was unduly favourable to the Exeter process. On the other hand, the apparatus used to represent the filter beds probably was such that organisms might get through these laboratory filters that would not get through the filter bed in actual use at Exeter. So that I hesitated to draw any definite conclusions.

1397. But would you say that with satisfactory land treatment, a disease germ was bound to be destroyed?—That is a very difficult question to answer. I think the probabilities are that, with a sufficient area of proper land and filtration through the land, the organisms would not appear in the effluent therefrom; but I am afraid it is impossible for me to say absolutely that this would be so.

1398. I was looking the other day at this pamphlet: "Worth and Crimp on the Main Drainage of London, and Dibden on the Purification of the Thames." I do not know whether you know the book?—I do not think so.

1399. There Mr. Roechling is speaking about the artificial filtration, and he says that: "He thought it "was very dangerous to force the hand of nature, especially "in a case where so little was known about the very in- "tricate processes by which the decomposition of organic "matter was brought about, lest in this attempt they "might create conditions which in the end might prove "disastrous. It was, for instance, well known that in the "process of putrefaction certain highly poisonous sub- "stances, such as ptomaines, toxins, etc., were formed, "and if an effluent containing these was discharged into "a small stream, which during very dry weather con- "tained practically nothing else but this effluent, he was "not sure whether they would not set up conditions "which would prove disastrous lower down the stream." Would you have any opinion to give as to a fear of that sort?—I do not think that there ought to be noxious materials of that kind in an effluent—a satisfactory effluent; but I see no reason why artificial filtration, properly conducted, should not produce an effluent which would be free from such material. The only question is, as to what would constitute a satisfactory process of artificial filtration.

1400. Quite so. You would not be afraid of creating anything?—I have seen no evidence that would lead me to suppose that new material of a dangerous sort would be created by artificial filtration properly conducted.

1401. Quite so. Now, as far as I understand, one of your principal doubts about the satisfactory nature of the septic tank and the filter was that the results varied so very much?—Yes.

1402. And have you any theory at all to advance as to why those variations were caused?—No, I have not. It is very difficult to account for them.

1403. It would not be that different men worked at it with rather different systems, would it—because the results were obtained by different chemists, were they not?—Well, I am hardly competent, perhaps, to express an opinion upon that matter. I have always been prepared to accept the analyses of competent chemists; I did not suppose that they would be likely to vary very largely one from another. I proceeded on the assumption that probably they would not vary largely one from another.

1404. As far as you know, the difference in the results would not be accounted for by the different times of the year or the amount of the flow?—No; on the contrary, these variations occurred in samples taken about the same time.

1405. There was a considerable difference of opinion, as far as I can remember, about whether the storm overflow should go through the tank or not?—One of the witnesses held the view that probably if the storm water was allowed to go through the tank it would damage the working of the tank, not only at the time, but for some time afterwards.

1406. But did not another of the scientific witnesses hold the view that it was better that it should go through?—All the rest—I am speaking from memory—I think the rest who gave evidence on that point thought that the action of the tank would at least not be appreciably harmed by it.

1407. And that the working of the filter would be equally satisfactory?—The filter or the tank?

1408. Well, of both?—The proposition was to treat the whole of the rainfall in the tank, but not on the filter subsequently. The filter would not be capable, I suppose, of doing that, and it was intended to pass the sewage that had been in the tank in large part directly on to the land and not throught the filters at all in time of heavy rain.

1409. At the present time it goes through the filters, does it not?—Yes. These are experimental works; and, as I tried to make clear, my difficulty with regard to the experimental works was this, that they did not take more than a small part of the rainfall; the pipe leading to the works is too small.

1410. But there was this question raised, was there not? Of course, in time of rain the effluent passes through the tank and through the filter much faster than it does in the dry time?—Yes.

1411. And was there not a difference of opinion among the scientific witnesses as to whether or not the working of the filter was equally satisfactory under such circumstances?—Yes, there was some difference of opinion; it was, I think, a difference of opinion in degree more than anything else. If my recollection is correct, I do not think that anyone claimed that filters and tanks would work quite as well in times of heavy rain, but some witnesses at least thought that there would not be a very great difference—that the result would be satisfactory at all events.

1412. I had a sort of idea that it was held that the sewage being so diluted as it would be in time of rain, the actual result would be quite as good, although the filter would not be so long at work upon it?—The tank or the filter?

1413. Well, both. I mean the final result would be as good from the sewage coming out very much diluted with rain as it would in the dry time, when the filter had been longer at work upon it?—One of the witnesses, I think, expressed that view.

1414. Yes, but the others did not?—The others did not.

1415. Then one of your principal objections to this is that the results are not certain. I suppose, as a matter of fact, the results of all land treatment vary very much?—Well, that I am afraid is a question which is very difficult to answer, too. Before answering that I should like to have a large body of evidence of land treatment under different conditions put before me.

1416. You would not be prepared to answer that?—Not at present.

1417. Would you be prepared to answer a question as to clay land? We have had some very strong evidence before us that clay land is practically worthless as a filter. Could you, from your experience, give any opinion upon that point?—I have had no personal experience as to that. What I know on that point is based on reading.

1418. In fact, you want evidence before you form an opinion?—Yes.

1419. Have you had much experience of land treatment?—No. I have occasionally seen sewage farms, but I have not had an exceptional amount of experience.

1420. It is conceivable that this Exeter treatment, even if it were successful in the case of simple sewage, would not succeed with trade refuse. You would not be able to tell us whether you considered that land treatment was satisfactory in the case of trade refuse, would you?—The same difficulty, no doubt, would arise with land treatment. It is perhaps a question of degree. With land treatment a great deal more land would be employed than material is employed in these artificial filter beds; one may be tolerably certain that some trade effluents would be just as bad for the organisms in the land as for those in the filter beds.

1421. This is my last question. Was there any evidence at Exeter as to whether the effluent if left to itself would become better or worse?—Yes; it had been kept in bottles, and the evidence on that point was, I think, in all cases satisfactory; that is to say, in all cases where that had been done in the laboratory the witnesses stated that the effluent remained clear, and had not developed any offensive smelll or deposited any matter in the bottom of the bottle.

1422. (*Mr. Killick.*) I think you held an inquiry at the time of the formation of the Mersey and Irwell watershed at Manchester; you were one of the inspectors holding the inquiry at Manchester at the time of the formation of the Mersey and Irwell watershed, were you not?—No, I was not.

1423. Oh! Have you any knowledge of the works within the area or that Committee?—No.

1424. With regard to the storm overflows in the sewage works, have you any opinion as to when they should begin to come into operation?—That, I think, is a matter that an engineer is more competent to decide than I am.

1425. (*Colonel Harding.*) You have told us that you had formed the opinion, that the effluents from the filter beds at Exeter were not sufficiently good to be turned into a stream, and that you thought some further treatment would be required?—Yes.

1426. There had been, had there not, considerable purification by filtration beyond the purification obtained by the tank?—Yes, a considerable degree of purification.

1427. I notice that, in one of the analyses it is stated that the purification obtained by the tank was 30 per cent. on the crude sewage, and that by the filter 80 per cent. on the crude sewage?—Yes.

1428. You, of course, have studied these analyses very closely. Would that represent generally the amount of purification, do you think?—Well, in the evidence I have given I gave the range of purification. The range was a very wide one—from 25 per cent. to 63 per cent. in the tank, or from 17 per cent. to 55 per cent., according to the method of judging; and 81 to 88 per cent. or 63 to 77 per cent. in the filters.

1429. The figures I named, judging by the oxygen absorbed, are below what you yourself give—from 81 per cent. to 88 per cent.; I was asking you 80 per cent.?—Yes.

1430. Would it not be possible to obtain further purification by further artificial filtration?—Yes, I should think there can be little doubt that you would get further purification.

1431. What I mean is that, if this filtration in this case has given us a very largely increased amount of purification upon that which had been obtained by the tank, probably a further, or a second, filtration would have given us an effluent fit to be turned into any stream, would it not—any stream, I mean, not for drinking purposes?—As a matter of fact, a great deal of work has been actually done in that direction elsewhere; the artificial filter bed is nothing new. And there has not only been work done in this country, but in America. The Massachusetts Board of Health has shown that you can get a very high degree of purification by passing sewage through artificial filters; only in regard to the Massachusetts work, in the vast majority of cases the proportion of sewage filtered per acre was very much smaller than in experiments in this country; instead of one million gallons per acre, as is attempted in many cases here, and as is the case at Exeter for the filter bed, in the Massachusetts experiments it is 40,000, 80,000, and 100,000 gallons per acre—a very different proportion. The filtration is much slower, and they get a better effluent; showing that a greater degree of filtration produces better results.

1432. Your opinion being that the effluent, as you saw it at Exeter, was not good enough, you think that further artificial filtration would obtain the desired results as well as treatment on land?—The judgment I have formed about the Exeter process was neither favourable nor unfavourable; I took a position of hesitation rather about it. It is conceivable that, with further knowledge, we might be able to use even the amount of filter acreage at such places as Exeter, and produce more consistently satisfactory results than are now produced; it might be necessary to add to the acreage, or you might find that you could do with the present acreage, or possibly even less. My great difficulty throughout was that there were many things unexplained by the evidence put before me, and perhaps, if we could get those cleared up, we might be able to find that we could deal with sewage even in the proportion to the acre attempted at Exeter; on the other hand, one must face the fact that we might find nothing of the sort; there is so much that remains to be discovered.

1433. The special point I wanted to get at was whether in your opinion it would be possible to obtain further purification by additional filters as well as by land treatment?—Additional filters being, I suppose, a greater amount of filtration?

1434. A second filtration?—That would come in effect to the same thing as a larger filtering area.

1435. Scarcely; it would be a second filtering area—a second and independent process?—I should certainly be disposed to believe that, with additional filtration, a better effluent would be produced; that is to say, with the two series of filters, I should expect that the effluent from the second series, having already passed through the first series as well, would be better than the effluent from the first.

1436. Then as to the possibility of any organisms going through into the streams. That would only have importance, would it, if the water of the stream were used for drinking purposes?—Or for fisheries—oyster fisheries, for example.

1437. Yes, but only in those cases?—Only in those cases.

1438. Did they try the experiment at Exeter as to the possibility of fish life in their effluents?—If they did, it was not brought to my notice.

1439. The Exeter scheme, I believe, has been extended, has it not?—Yes.

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1440. To deal with the whole?—The whole sewage of the city.

1441. Yes. You do not know when it is likely to be in operation?—No, I cannot tell you.

1442. (*Dr. Russell.*) Your business at Exeter was to consider the case of the scheme as it was presented to you by the authorities?—Precisely so.

1443. It was not any part of your business to point out portions of the evidence which were defective, which might have been supplemented if their attention had been directed to them?—Well, yes, as a matter of fact, as I have stated in this evidence, we had two inquiries—a preliminary inquiry in May, and a subsequent inquiry in November; and at the preliminary inquiry in May my colleague and I came to the conclusion that in certain matters we would like to have additional evidence, and we let the Exeter Town Council know that, and that additional evidence was partially provided for us at the subsequent inquiry in November. Some of it, however, was not provided; that, for example, dealing with the influence of heavy rainfall; the size of the pipe leading to the experimental works was such that they could not amplify that evidence for us.

1444. The ultimate result was, as you said to Colonel Harding, that you were left in a state of suspense and hesitation as to various points?—Yes.

1445. I notice in your enumeration of the reasons which led you to the conclusion that it was desirable that there should be further purification by treatment on land, they very largely result in pointing out that, in the matter of chemical analyses, the nature and number of organisms present, as to the influence of rainfall, and the influence of seasons, you had not enough evidence to enable you to come to an opinion?—No; more particularly as regards the variations of analyses and the rainfall question. On the seasonal question, I also thought the evidence was somewhat lacking, but I did not regard that as being quite so important as the other two, because there is already a good deal known in that matter—not as regards the septic tank itself, but as regards filter beds.

1446. Yes; so that the decision bears not absolutely against the principle of this biological treatment, but it points rather to the necessity of such inquiry as has been entrusted to the present Commission?—Quite so.

1447. And, knowing something of the results of treatment on land, you attached that recommendation to your report—knowing something more definite as to treatment by land than is known as to treatment by this biological filtration?—Quite so. I had some knowledge, based on evidence in the past, as to what might be looked for from the treatment of sewage on land, but the evidence as regards artificial filtration, combined with the septic tank, was less in amount.

1448. Still, the result even of treatment by land depends a good deal upon definite conditions and care in the application of it?—Yes.

1449. It is not absolutely and necessarily successful in biological filtration?—No; I quite agree.

1450. (*Professor Ramsay.*) I have not quite realised how long the liquid lies in the septic tank. You give the dimensions of the tank from end to end, and it would be possible to calculate it, and you, no doubt, did; how long could it be said that the liquid, which goes in at one end, stays in the tank before it flows out at the other, under normal circumstances?—The dry weather flow of 35,000 gallons, I think, works out in the case of the experimental works to about forty hours' stay.

1451. Forty hours' stay?—The average flow being 55,000, the average stay would be not more than twenty-four hours. As to what happens in rain, the evidence is unsatisfactory, for the reasons I have stated.

1452. Might I ask you if you have noticed the character of the substances; I suppose paper forms a partial element of the sewage?—Yes.

1453. Does it remain in the tank, or is it destroyed before it issues?—During the examinations I myself made of the effluent from the tank, I never saw any paper. I saw no solids, except small suspended black particles; I saw nothing bigger.

1454. Would the paper be removed by previous straining?—No; there was no previous straining when I saw the tank, and I understood from the evidence given that they did not strain the sewage.

1455. There has been no analysis of the gas escaping at the top, has there?—Yes, there has.

1456. Do you know what the gas consisted of?—That is given in this report by Dr. Rideal.

1457. Largely marsh gas and hydrogen. Then you stated that the effluent from the filter beds usually has a slight opalescent tint; is that due to the presence of organisms?—Do you know if the opalescence is formed by a large number of organisms escaping or not?—I cannot say what the opalescence is due to.

1458. That was not explained?—That was not explained.

1459. Is anything known about the nature of the organisms which were affected?—There has been some inquiry made into them. You will find in the printed matter a report by Dr. Sims Woodhead, which gives some account; but the knowledge is very partial knowledge, and leaves a very great deal unexplained. Of course, it is a very vast subject, and no doubt Dr. Woodhead had not the opportunity of going into it with sufficient fulness.

1460. He gives the number of anaerobic organisms, and so on?—Yes.

1461. (*Major-General Carey.*) Would you explain how samples were taken from the filters?—They were partly individual samples taken at a given moment, and partly they were mixed samples.

1462. I am referring now to the mixed samples?—If you will allow me to refer to my papers, I can say how that was done. It is rather complicated. The samples from the filter beds?

1463. From the filter beds, yes?—The mixed samples were taken in the following way: Five samples equal in amount, amounting to 500 cubic centimetres in each instance, were taken of the effluent within one, three, six, ten, and twenty minutes respectively of the time when the discharge of the filter beds had commenced. These times are the approximate centres of the five periods occupied by the discharge of the five-fifths constituting the total effluent of the filter beds. Then the five samples procured in this way were added together, and constituted a mixed sample to be submitted for analysis, a total amount of 2,500 cubic centimetres

1464. Would that include the first rush from the filter?—Yes.

1465. Or would they wait for a minute?—They say that the first sample was taken in the first minute; the next sample was taken three minutes after the discharge had begun, and the next six; the bulk, therefore, of the samples were taken within the first few minutes. It must necessarily be so, because the greater bulk is discharged in the earlier part of the emptying of the beds.

1466. I rather wanted to know whether a fairer mixed sample could not be produced by taking the first rush from the filter, say, for one minute, and then at intervals, distinct intervals, until the filter was empty, say, of ten or fifteen minutes each, for one minute? They would then get a much larger volume of the effluent in the first minute, on account of the rate at which the effluent would be discharged, and at the end, when the filter was nearly empty, there would be hardly anything at all, a mere dribble in that minute. When you mixed all those samples together for a mixed sample, you would get a very different result as far as the analysis was concerned. Do you see what I mean?—Yes, but I do not think that would be fair, because you would get an infinitely larger proportion of the earlier outflow than of the later—an infinitely larger proportion to the total amount discharged. The endeavour of the persons who took these mixed samples was to make the amount taken in each instance proportional to the total discharge. They divided the total discharge of the filter beds, some 8,000 gallons, into five-fifths; they reckoned how long each fifth took to discharge, and they took a sample from the middle of each fifth of precisely the same amount. In that way they concluded, and it appears to me with justice, that they had got a fair mixed sample.

1467. At the same time the great mass of the polluting effluent would go into the river within the first two or three minutes, or the first few minutes?—The first portion discharged is not so good as the later, but, in taking a sample in that way, they had the same amount of each of the five portions. If they had taken, say, a sample a minute for the first half-hour or so, they would not have got at all an average sample; they would practically have got a sample of the earlier discharge, because there would be a very much greater proportion of the earlier discharge than of the other in amount. I think they took it in the fairest way; but, of course, information of that kind ought to be supplemented, and was to some extent supplemented at Exeter by analyses taken also at individual

moments—such as a sample taken at the very beginning, or twenty or twenty-five minutes afterwards, and separately analysed.

1468. I mean, if a river inspector went round and took his sample at the first rush when let off from the filters, he might condemn it, and say that it was not by any means satisfactory, and might arrive at very different conclusions from what the results of the analyses would lead you to expect?—I think myself that both mixed samples and individual samples ought to be taken.

1469. Then there is another point. You say it was shown at the inquiry that the refuse entering the sewers from these works was not of a quantity or character likely to affect injuriously the septic tank system? Those are experiments not made at the Belle Isle Works?—They were made in laboratories, samples of the Exeter sewage being mixed with Exeter trade effluents.

1470. In the laboratory?—In the laboratory.

1471. There have been no experiments made at all at the experimental works with mixed sewage?—None whatever; no trade refuse has ever been treated there.

1472. And you did not see the Yeovil works, the works where they were treating the mixed sewage in the septic tank?—No; I did not see the Yeovil works.

1473. You considered, I think very rightly, that very much more evidence should be obtained with respect to the bacterial action which goes on in septic tank systems?—Yes, I think so.

1474. That at present the evidence on that point is quite insufficient?—Quite insufficient.

1475. Have you formed any opinion as to the treatment in the septic tank only, without the filters—whether that might be considered equivalent to chemical treatment and precipitation without land?—I have precisely the same difficulty in answering that question as I have in giving a definite answer as to the effect of the whole process. There are those difficulties which I have mentioned about rainfall particularly; I should like to know more on those points. It may prove to be quite as good; on the other hand, it may prove to be better, or worse. But before venturing on a definite pronouncement, I should like to have further evidence.

1476. (*Sir Richard Thorne.*) I believe I am right in supposing that at Exeter they have a piece of land on which they can deal with the effluent from the filters?—Yes, that is so.

1477. When you were down at Exeter, was that piece of land in use for that purpose?—No.

1478. Then the results you dealt with were entirely obtained from the use of the tank, plus the filters?—Quite so.

1479. Now I noticed that you said that the number of micro-organisms present both in the tank effluent and in the effluent from the filter beds was very great. Was any evidence brought before you as to the character and quality of those micro-organisms?—There was a little, but it was very inadequate from the point of view I was regarding the process from. You will find some of it given in the printed matter, page 37.

1480. As we have not that printed matter before us, would you mind just quoting the essential points of it, so that it will be down in evidence?—In the main, the evidence with regard to the qualities of these organisms was as to whether or not they were anaerobic or aerobic, and as to whether or not they were liquefying or non-liquefying. In addition to that some evidence was given as to the particular characteristics of eight organisms that had been separated from the crude sewage and from the tank effluent.

1481. Could you tell me whether some of those organisms would be likely to give rise to offensiveness if admitted into running water?—Of the organisms that were——

1482. That were found to be in the filter effluent?—Well, it is not easy to say definitely, because these organisms are not mentioned by any name at all. I mean to say, that apparently they are regarded as organisms not at present classified.

1483. Is there any evidence of which you are aware at present which would really help the Commission to differentiate between the quality as contrasted with the quantity of the organisms that are found in the filter beds?—I am not sure that I quite grasp what class of evidence you mean.

1484. Evidence was brought before you to show that the amount of micro-organisms in the filter effluent was very great?—Yes.

1485. Was any evidence brought before you to show what was the character, that is to say, the quality, of the organisms that made up this large body?—The evidence as regards the character was of the kind I have mentioned—whether or not they were anaerobic or aerobic, or whether they were liquefying or non-liquefying. And also as regards the effluent, experiments were made with the sewage containing certain organisms, claiming to show that this mixture of sewage and these particular organisms underwent nitrification if kept in bottle. But it is very doubtful whether one can accept these experiments as showing that pure cultures of the organisms in each case were used, and that such cultures really brought about nitrification. I have very serious doubts about it. Judging from the work which has been already done elsewhere in that direction, I have doubts whether those organisms did give rise to the nitrification indicated by the experiment.

1486. You have referred to some experiments which were made with the typhoid bacillus. Were those the result of purely laboratory experiments with the organism, or were they experiments with the actual effluent from the filters?—The culture of typhoid bacilli was added in the laboratory to sewage which had been collected and allowed to stand, and this mixture was set aside for forty hours, so as to allow the influence of the sewage to be exerted on the enteric fever organisms; that influence being, it was supposed, equivalent to the influence that the tank would during that space of time exert. And then, after that, the next stage was to pour the mixture upon an artificial filter, which was composed of a tube some 4½ feet long, containing the sort of material which the filter beds contained. Then, after the lapse of a given number of hours, the contents of the tube were allowed to drain off, and a sample was taken of the effluent, and that sample was examined for the number of enteric fever organisms present. Comparison was then made with the numbers present in the original sewage, to which the enteric fever culture had been added.

1487. Can you tell us generally what the result of those experiments was?—Generally the result was that there was a great diminution in the numbers of enteric fever organisms. Only a few enteric fever organisms passed through the whole experiment, and came out in the effluent at the other end.

1488. Then the circumstances of this laboratory experiment would not in any way be final as to the destruction of the typhoid organism?—No. I think that the experiment as performed was open to objection in the way I have already pointed out; it was not conclusive.

1489. Could you give us any idea, limited as I know you are by the Exeter experiments, as to whether in your opinion this system is likely to be satisfactory apart from land treatment of the filter effluent?—It is very difficult to answer such a question otherwise than in a provisional manner. The evidence at present is so incomplete that it is really difficult to judge what the process may be able to achieve.

1490. Yes?—It may prove to be sufficient, and it may not.

1491. Could you say anything further if I limited you entirely to domestic sewage, to the exclusion of manufacturing refuse?—No; I have precisely the same difficulty.

1492. In your statement you described the process in the tank as consisting mainly of the conversion of part of the solids in suspension into solids in solution, and of the breaking down of complex organic compounds into simpler compounds. Are you able to give the Commission any more detailed information as to how that is brought about; whether, for example, it is brought about by organic matter being destroyed or utilised in the rapid multiplication of organisms, or whether it is some other process that is going on?—If I understand the question rightly, you mean whether the changes come about owing to the presence of micro-organisms?

1493. Owing to their presence, and owing to the fact of their multiplying rapidly. If they multiply rapidly, I assume they would require for their growth and sustenance organic matter; that organic matter would be taken up in the process of multiplication, and that might lead to the breaking down of the complex organic compounds into simpler compounds?—What evidence was given went to suggest that that was the way it was brought about.

1494. Yes. Then, as a matter of fact, you expect to find in the tank effluent a larger number of organisms than in sewage proper?—Not necessarily. That is precisely one of the points upon which one wishes to have

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further knowledge. The contention is that this work is done by particular organisms. Sewage contains presumably a large quantity of diverse organisms, of which many may be entirely useless for the purpose of the process; only a few probably are really effective, and the result might be that, in the tank effluent you would get a smaller number of organisms than in the sewage, yet those might happen to be the very organisms that were wanted; the redundant ones may have been killed off, and the effective ones may survive. But at the present moment our knowledge is very much restricted by the limited amount of experiment that has been made. We do not know how far that is the case.

1495. May I take it, from the fact that, after your visit to Exeter, the Town Council were advised to pass the effluent from the filters over land, that on the experience derived from Exeter, you did not regard the effluent as a proper one to flow into a running stream?—No, I did not.

1496. I believe I am right in my surmise that, until these bacteriological methods of sewage disposal came forward, you were not employed by the Local Government Board in inquiries as to sewage disposal?—I was not.

1497. Would that prevent you from forming any general opinion as to the value of this process as compared with really good chemical processes?—Before forming such a judgment, I should like to have intimate knowledge of a good many more facts than I have now. I have a general acquaintance with the matter, derived from a certain amount of inspection of sewage disposal works, and from a certain amount of reading. But before answering such a question as that, I should like to have an opportunity of carefully going into the Exeter and other data again, and having them freshly in my mind before making any comparison of the kind.

1498. Then I assume we may take it that, before the matter can be settled as to whether the septic system so-called does provide an effluent that is proper to go into running streams a great deal more inquiry and investigation is necessary?—That is my view.

1499. (*Chairman.*) There was one thing I wanted to ask you. You said that there were a good many things at Exeter that were unexplained. Could you amplify that at all?—I am not quite sure that I properly understand your question.

1500. Your general position as regards the Exeter system is that it does a good deal, but that you are not quite certain yet how much it actually does, or how much it might do?—Or how much it might be trusted to do uniformly.

1501. Yes. I think you said that on several points you had no explanation as to why things had occurred?—I did not understand the variations in proportion of certain chemical constituents.

1502. You referred only to the variation in the analyses?—Yes.

1503. Do you suppose that the analyses showed every constituent that was in the effluent, or might there be things in the effluent which no analysis could detect?—It is quite possible that there may be things in the effluent which analysis cannot detect. I am afraid that chemistry does not give us quite the amount of information we should like to have about these effluents We want to know a little more about the quality of the things that chemistry indicates. Chemistry tells us that there is something which it calls "Albuminoid ammonia"; we want to know exactly what that albuminoid ammonia is; it may in one instance contain a material which is liable to become a very offensive material, while in some other instance the albuminoid ammonia may contain a very different material, perhaps potentially a much less offensive material.

1504. Then as regards the disappearance of the solids, were you surprised to find to what an extent they did disappear?—I think I may say I was. I had never, in the course of my experience or reading, come across anything analogous to it.

1505. (*Professor Ramsay.*) Might I ask if you are referring to the septic treatment?—To the septic tank, yes.

1506. (*Chairman.*) Did you take any evidence as to the question of temperature, whether in hot weather or in cold weather there was any difference?—No; we had not any evidence save of the most general sort on that subject.

1507. There is nothing done in a hard frost or anything of that sort to keep up the temperature is there?—Nothing.

1508. And you said you had some evidence about the destruction of the disease germs. Could that evidence be separated at all in this way, as to how far the destruction takes place in the tank, and how far after it has left the tank and in the filter?—That evidence was actually given, distinguishing between the two stages. What proportion of the destruction takes place in the tank and in the filter respectively was shown as a laboratory experiment.

1509. If you could just give it us again, so as to get it into the evidence, I think that it would be rather an advantage?—Yes. The experiments were not so conducted that actually the organisms of enteric fever were placed in the tank; instead of that, they were placed in sewage in the laboratory under conditions held to be the nearest approximation that could be easily got for the tank.

1510. Yes?—And experiments were adduced as showing the length of time that typhoid bacilli lived in sewage, and the proportion of them that survived after a given number of hours. That resulted as follows:—That after twenty-four hours, 76 per cent. remained alive.

1511. Remained alive?—That is what we may regard as the tank experiment.

1512. Yes?—And after forty-eight hours, 60 per cent. remained alive. Then, after subsequent treatment in an artificial filter, 10 per cent. was the amount that survived. That is to say, from 30 to 40 per cent. were destroyed, under conditions representing the tank, and by the time they had passed through both tank and filters only 10 per cent. remained; showing that of the 60 to 70 per cent. that had survived the substitute for the tank, from 50 to 60 had been disposed of by the filter beds.

1513. Thirty to 40 per cent. were destroyed in the sewage, and 50 to 60 per cent. of the remaining 60 or 70 were destroyed subsequently?—Yes; accepting the process as the laboratory equivalent of the tank and filters.

1514. Generally your conclusions would be that the artificial filter and the tank combined do a great deal towards purification?—Yes.

1515. The filter at present, I think, is coke breeze?—Furnace slag in most of them.

1516. Suppose the effluent from that was passed again through a filter of a somewhat different material, would you be disposed to think that that would have a further purifying effect?—Yes.

1517. You would?—Yes.

1518. (*Colonel Harding.*) I just want to ask Dr. Thomson this. In one of his answers he told us that the effluent from the septic tank contains in suspension a considerable amount of finely divided black matter; and later he said that the effluent from the filter beds was at first slightly opalescent, but later was quite clear. Therefore, I take it that the finely divided black matter was changed into a liquid or gaseous form, or would remain behind in the filter as solid matter?—That is so, almost entirely. There was evidence given at the inquiry that in some instances a little suspended matter appeared in the final effluent from the filter beds; but the great bulk of the evidence was to the effect that suspended matter was practically absent; that is to say, quite absent, or very little of it.

1519. Was any evidence brought before you to show whether there was any accumulation of this finely divided black matter in the filter beds?—No.

1520. That is, whether there was any reduction in the capacity of those beds?—There was no evidence to that effect.

1521. (*Sir Richard Thorne.*) Did you see the effluent before it passed into the river on the spot?—Yes, frequently.

1522. What was the general condition of that to the eye?—To the eye the effluent was usually slightly opalescent. when the filter began to discharge, and for a little time after it began to discharge; gradually it got clearer, until, finally, when only small dribbles were coming from the filter, it was quite clear.

1523. Should you say the bulk was opalescent, or the bulk was clear?—I should say the bulk was opalescent.

1524. So far opalescent, do you mean, as to make it improper to enter an ordinary watercourse, or was it only slightly so?—Only slightly. I should not have regarded that in itself as being sufficient reason for not allowing it to enter a watercourse.

1525. Then a very great effect had been produced in so far as the eye could judge?—A very great effect.

1526. (*Colonel Harding.*) Did you try the experiments

with the effluent by keeping it in open or closed bottles with the idea of finding out if there was any subsequent decomposition or putrefaction?—I personally did not do that; but it had been done, and evidence was given at the inquiry by those who had done it to the effect that they had made these experiments, and that the filtrate had remained clear and inoffensive. At the same time I think I ought to say that I am not sure that those experiments are quite trustworthy. All laboratory experiments ought to approximate to nature as nearly as possible, and this particular class of laboratory experiments does not approximate at all to nature. The sample is put in a bottle, and kept in a room, and it remains there under the same set of conditions for an indefinite period, a set of conditions which varies little save as regards light. But an effluent that is discharged into a river is under very different circumstances. You have the rise and fall of the river; material in the effluent deposited possibly upon the banks, or mud, and decomposing; and it, to my mind, at least, is not by any means certain that matter, which in an effluent is in a state of solution, may not under those circumstances become again in a state of suspension. I know that at the inquiry it was stated to us in evidence by at least one distinguished chemist that that would not occur, but I confess to having some hesitation in accepting that statement. I do not think that these laboratory experiments are such as could settle a problem of that kind. I should like to see a closer approximation to the conditions of nature before I should be willing to accept those experiments as conclusive.

1527. (*Chairman.*) Did they not analyse the river water just below where the effluent was put clean into it?—They had a bacteriological examination of the river water made there, and also a half and a quarter of a mile down the river; I cannot recollect whether or not there was a chemical examination made of the water of the River Exe.

1528. (*Professor Ramsay.*) It is a tidal river, is it not, there?—Not at that point; at the point where the experimental works are situated, and at the point where the effluent from these works goes in, it is not a tidal river. There is a weir about half a mile below, and up to that weir it is semi-tidal; that is to say, occasionally tidal; but above that weir it is not tidal.

1529. (*Major-General Carey.*) But the effluent from the land would go into the semi-tidal waters?—That will go into the semi-tidal river.

1530. (*Sir Richard Thorne.*) In answering Colonel Harding as to the decomposition of the effluent, you said that the effluent remained clear. Does that mean to imply that for this purpose the effluent was taken when it was clear, and not when it was opalescent?—Ah, well, the effluent may have been opalescent to begin with. It was clear at the end of the experiments; it may have been opalescent at first.

1531. Because it is possible to imagine that the opalescent effluent would behave differently from the one that is clear in that respect?—Yes.

1532. (*Mr. Killick.*) A clear effluent is very often a very bad effluent. As you point out as it enters a stream it is liable to secondary decomposition?—Yes.

1533. It comes to this, does it not: Unless the effluent is analysed carefully, it is impossible to tell what condition it is in, or what may happen to it?—Perhaps not always possible on analysis alone. I think it is desirable to observe actually what does happen in the state of nature rather than to collect a sample and put it in a laboratory. I have had, on more than one occasion, laboratory samples of that kind under my notice, and I have subsequently looked at the stream into which the effluent was discharging, and found the stream in a foul condition from the very effluent that had produced samples, kept in the way I have described, that really appeared to be very good.

1534. A satisfactory effluent would depend entirely upon the effluent itself, and upon the character of the stream into which it was discharged?—I think that is a thing which ought to receive consideration. An effluent might create no nuisance in one stream, yet it might create a great nuisance in another one. It depends partly on the size of the stream, and partly on the character of the stream.

1535. The swiftness of the stream?—Probably on the amount of oxygenation of the water as much as anything, and on the bulk of the water relatively to the bulk of the effluent.

1536. And also the question of the effluent passing into fresh water, and passing into the tideway, would deserve consideration, as the effect would be very different?—Yes, that also, because probably the conditions of salt water as affecting the life of micro-organisms, and possibly as regards chemical change, are different from those in fresh water.

1537. (*Major-General Carey.*) Salt water would tend to preserve it, would it not, from the pollution, or prevent it being oxidised by the oxidation of the water?—I am not quite sure how far that is so. As regards micro-organisms of certain sorts, at all events, they can live for a considerable period in salt water. I am not prepared to say as to the relative effects chemically of salt water and fresh water on the effluent.

1538. (*Mr. Killick.*) That would delay secondary decomposition a sufficiently long time to allow the effluent to pass away?—Possibly. I do not feel myself justified in saying much about that; it is not a thing I have had an opportunity myself of studying. I think it is a thing which requires to be considered, but I am afraid I am not competent to express any opinion.

1539. (*Chairman.*) You did not get any particular valuable results from the analyses of the river water at Exeter?—From the biological examination?

1540. Yes?—No, because those experiments were really intended to show what the effluent did to the river water in the way of polluting it. But the river water also received the whole sewage of Exeter untreated, except that portion treated at the experimental works. And also, I ought to say that the experiments were too few in number to afford basis for drawing conclusions. There was one part of the experiments which one might have expected useful knowledge from—where the final effluent, before it had passed into the river, was injected into guinea pigs—I believe, without evil result. But the experiments were only two, I think, and that is too small a number to form any estimate upon.

1541. Injected into what?—Guinea pigs or rabbits, my memory does not serve me to say which.

1542. (*Professor Ramsay.*) May I ask if the only filtering medium used at Exeter is furnace slag?—In four out of five filter-beds it is furnace slag, and in the fifth coke breeze.

1543. Have you any idea which purifies best?—There was not any evidence given at the inquiry to show which of the two purified best.

1544. Another question I want to ask as regards the temperature. You say that there is no record kept of the temperature in the septic tank, but do you know if it is higher than the atmosphere? Is the septic process one which develops heat?—I am afraid that if I said there was no record kept, I went further than I intended. I should not like to say that, because there had been some notes taken of the temperatures of the contents of the tanks; but there was no systematic evidence laid before us as regards the relation between the temperature and the effect on the sewage. That was what I meant to say.

1545. I quite understand that, as regards the time of the year, but do you happen to know whether it was found out whether the temperature of the filter was higher than that of the air, or not?—I am not sure about that.

1546. Of course, in the ordinary decomposition of manure the temperature rises very largely?—I do not think there was any evidence given as to the temperature of the tank contents as compared with the temperature of the air. I believe we had one statement made to us as regards the temperature of the tank contents and the incoming sewage.

1547. That would be the same sort of thing?—That, I believe, was stated, but I am afraid I cannot at this moment find the reference.

1548. (*Dr. Russell.*) About those typhoid bacilli. You are aware that a very large proportion, especially in our towns, of the typhoid fever which exists in the country is treated in hospital?—Yes.

1549. Can you say anything as to what is done in the way of endeavouring to take advantage of that opportunity for disinfecting the sewage to kill those typhoid bacilli before they are allowed to escape from the hospital?—You mean, in what proportion of instances?

1550. Do you think there is any effective attempt made by any hospital that you know to disinfect the sewage which is discharged into the public sewers?—I believe some of them attempt to do so, but I hesitate to say how far it is effective.

1551. That is the point. Do you think that any process that we can use is likely to be effective?—It is a very difficult thing to do—in practice, I mean.

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1552. As regards the portion of typhoid fever which is treated at home, I suppose, really there is no effective disinfection takes place in that case at all?—I should say in a very small proportion.

1553. Yes. So that, wherever you have domestic sewage, especially in the towns, it must have every chance of being full of typhoid bacilli?—Well, at all events, I think one may say that at certain periods of the year there would probably be a good deal of infective material in the sewers.

1554. Only speaking from personal recollection of my observation of what has been done in the way of practical experiments with reference to the habits and conditions which govern the vitality of the typhoid bacillus, my impression is that one or two points have been experimentally cleared up, and that one is that the typhoid bacillus fares very badly in domestic sewage?—There have been a good many experiments on that point, I believe, and they do not quite agree. But I think one may take it that in the main the experiments go to show that, after a time, the typhoid fever bacillus does disappear from raw sewage in which it is kept.

1555. They have to encounter an enormous rivalry of other bacteria, which is not conducive to their vitality?—That is a theory put forward to account for the fact that they do disappear.

1556. Then there is another point which seems to be in my recollection, that the typhoid bacillus certainly does multiply in polluted soil?—Yes.

1557. That being so, it seems to follow that in all processes you have got that question to consider, as to what is the fate of the typhoid bacillus in all processes for dealing with domestic sewage?—Yes.

1558. It is not merely with regard to the bacteriological method, but artificial filtration and land filtration, and precipitation, and the whole category?—Yes.

1559. And if the bacillus multiplies in polluted soil, there is a presumption as against land filtration?—That is one of those things regarding which one would wish to see experiments; because if the theory be accepted that it is the presence of other organisms that are unfavourable to the continued existence of the typhoid bacillus, one would expect that in polluted soil the enteric fever bacillus should cease to exist. In other words, I am not disposed to accept any proposition of the kind unless I have actual experiment to show me what happens. It is extremely difficult to draw such an inference in our present state of knowledge, because there are probably so many things affecting the life history of the enteric fever bacillus of which we are quite ignorant. I do not care, therefore, to go beyond the inference which may be drawn from actual experiments conducted in a particular case.

1560. At any rate, the issue in my mind is this, and I think probably you will agree with me, that you cannot assume, because we hear so much of bacteria in connection with biological filtration for town sewage, that it is there alone the question of what is the ultimate fate of the typhoid bacillus arises?—No. That is, as regards the artificial filtration of sewage, only a part of the problem, just as it is with any other treatment of sewage.

1561. (*Sir Richard Thorne.*) May I ask you, with regard to this trade refuse question, whether there is not some evidence to show that excessive moisture in soil is not favourable to the growth of the typhoid bacillus? Is it not rather a small amount of moisture such as would hardly be represented by land which is under irrigation which is favourable?—To the extent of showing that excessive moisture is unfavourable, yes; but, there again, I have the same difficulty when you apply this principle to a particular instance. Unless that particular instance is precisely on all fours with the experiments conducted, I should hesitate to draw a conclusion.

SIXTH DAY.

Thursday, 28th July, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS (*Secretary*).

Mr. W. S. Crimp, M.I.C.E. 28 July 1898.

Mr. W. SANTO CRIMP, M.I.C.E., called; and Examined.

1562. (*Chairman.*) I believe you are a Civil Engineer practising at 27, Great George Street, Westminster?—Yes, I am.

1562. And that you have had twenty-five years' experience entirely devoted to municipal engineering work, that you are a member of the Institution of Civil Engineers, a member of the Board of Examiners of the Municipal and County Engineers, a Fellow of the Sanitary Institute and of the Royal Meteorological Society, and that you had charge for twelve years of sewage disposal works, namely, eight years at Wimbledon, and four years as one of the district engineers to the London County Council, in charge of the engineering works on the north of the Thames, including the outfall works at Barking?—That is so.

1564. That your firm has advised 104 public bodies on matters relating to sewerage and water supply, among those bodies being the Corporations of Glasgow, Manchester, Salford, West Bromwich, Shrewsbury, Bridgnorth, Rochester, Taunton, Tiverton, and Bristol, together with a large number of Urban and Rural District Councils?—That is so.

1565. I believe you have had practical experience in the treatment of sewage on land and by means of artificial filters?—I have.

1566. By chemical processes, and also carried out works for discharging the sewage into the sea?—That is so.

1567. Now, with regard to the flow of sewage to the works, can you give us some notes on the manner in which sewage is discharged at the outfall under varying circumstances?— I think it is best to begin with the gravitation systems. There is a distinction to be drawn between gravitation systems and those in which the sewage is pumped. I can, and would prefer to, begin with gravitation systems. These may be divided into two classes—firstly, those in which the sewage and rainfall are carried off by the same system, as is the case in London, Glasgow, Bristol, Manchester, and most of the large towns; and secondly, those in which the so-called separate system is in operation, with regard to which it may be said that, as a general rule, the street water and the water from the fronts of the houses is excluded from the sewage system, but the rainfall from the back roofs and yards is generally admitted. In the case of the first-mentioned system, the wet-weather flow may exceed the the dry-weather by upwards of 100 times, and storm overflows are arranged upon the system at suitable points, by means of which the excess over a certain quantity is discharged into the nearest watercourse. In designing works of this kind, the out-

fall sewers are of varying capacities, according to local circumstances. As a general principle, the outfall sewers of a very large system like that of London may be of less capacity relatively than those of smaller towns, because the maximum flow from those parts of the district remote from the commencement of the outfall sewer does not arrive until after the maximum flow of those portions nearer the head of the sewer has passed off. The London northern outfall sewers can carry off about three times the present dry-weather flow, but in smaller systems it is usual to provide a carrying capacity equal to about five or more times the dry-weather flow, and as outfall works usually contemplate dealing with the sewage of a larger population than that draining into it when the works are completed, the carrying capacity may reach as high as ten times the dry-weather flow. Dealing next with the second class of works, about the same provision is usually made in designing the main outfall sewers. The matter is of some importance as relating to sewage disposal, because in the largest systems—as well as in the smallest—the outfall sewer may become fully charged within the space of fifteen minutes. I have known that in the case of the large northern outfall in the case of a heavy fall of rain, fifteen minutes after the rain has made its appearance in the sewer, the sewer has become fully charged, and in such cases, unless the sewage disposal works are designed with that contingency in view, they must inevitably fail to perform their functions properly. I consider that this question is of very great importance, because in laboratory experiments no account is taken of the circumstance. In these experiments the sewage is usually treated with great exactness. If chemicals are employed the exact dose can be accurately measured, the proper period of rest can be given for the deposition of the suspended matters, and the supernatant liquid can be drawn off in such a manner as not to disturb the sludge, or, if experiments are made in the same way with artificial filters, the same exactness obtains, and no account is taken of the greatly varying conditions under which the sewage arrives at the disposal works under ordinary circumstances. Being indoors, the experimental apparatus employed is not subject to the vicissitudes of weather, and, as a general result, works based upon the experience gained in the manner suggested are frequently ineffectual. Under ordinary circumstances, again, the sewage arriving at the disposal work varies in volume and in quality at different hours of the day, which is another disturbing factor. In a table which I prepared for my work on Sewage Disposal, I give the discharges during various periods of time, the dry-weather flow being that referred to in the table. One inference that may be drawn from the table is that where there is leakage in the sewers, as, for example, at Aylesbury, there is a tendency for the flow to become equalised.

1568. What observations would you like to offer with regard to those cases where the sewage is pumped?—These cases may be divided into two sections. In the first place, in large towns where pumping is carried on day and night, the volume pumped approaches very closely the normal flow of sewage, and in those cases there is no material difference as regards rate of flow to the outfall works between those towns and the ordinary gravitation systems; but in the smaller towns, where the sewage is all pumped during the day, and a storage tank is provided for the night flow, the circumstances are different, because the sewage is as a rule discharged at the sewage disposal works between the hours of 6 a.m. and 6 p.m., but not continuously during that period, as the pumping machinery is usually constructed in duplicate in order to deal with a certain proportion of the rainfall and in case of breakdown, and each set is usually sufficient to pump the dry-weather flow in about six hours, so that the two sets when working together can pump eight times the dry-weather flow. This factor has to be considered in designing outfall works, so that the sewage can be properly purified when the maximum flow is delivered at the works.

1569. What is the general effect of the varying conditions to which you have referred?—The general effect is, that works which receive the sewage from a pumping station, have to be larger than those in which the sewage is discharged by gravity during the whole of the twenty-four hours. I am sorry I have not been able to extend that, but I have been at an inquiry at Croydon during the past three days.

1570. Oh, I think these general questions will be very interesting. What we should like to ask is, if you would give us the experience first of all of the different classes of soil that are used for sewage disposal and the population in such soils?—Well, my Lord, I would prefer to begin with the best class of soil I think, and work down to those that are really not suitable at all. The best class of soil that I have found anywhere for purifying sewage is the alluvium found in most river valleys; not in all, of course.

1571. In some river valleys?—In most river valleys. The Thames, for example. There are many square miles of beds of these river gravels in the Thames valley which, when above flood level, are extremely well adapted for the purpose. The best soil I know usually consists of about fifteen inches of good porous top soil and under that a bed of gravel. That I consider the very best soil, and I place the population limit in rather a different way from that in which it has been done as a rule. My experience is, that it is a question of gallons per square yard quite as much as persons. Now, in one of the farms that I have had an opportunity of examining very carefully with regard to this matter having this very first class soil, I find that that soil would purify effectually sewage effluent after it had been clarified at the rate of 30,000 gallons per acre per day constantly without becoming sewage sick, but that was its limit.

1572. 30,000 gallons per acre per day after it had been clarified?—After clarification in settling tanks. That was the maximum amount of liquid; you can regard it as sewage effluent or simply as liquid; but that was the maximum amount of liquid that would pass through the soil and admit of the the soil draining itself, so as not to become sewage sick.

1573. That being the very best soil you know?—That being the very best soil I have ever found. It follows from that that if your average sewage flow is thirty gallons per head per day, you would be having 1,000 people to the acre; but if, on the other hand, owing to the leaky condition of the sewers, the sewage flow amount to sixty gallons per head per day, you are only putting on the sewage of 500 people to the acre. If you could find a place where the sewage flow is as low as twenty gallons per acre per day, then you would have a larger number of persons per acre relatively; but in my view it is most important in all these cases that the volume of sewage per acre should be one of the standards, and a more important standard than the number of persons.

1574. When you say clarification, you mean, merely passing through settling tanks?—After having been chemically treated, in which it had been chemically treated first, and practically all the suspended matter removed, and then the clarified effluent applied to land.

1575. That is what happens with your very best soil?—That is what happens with my very best soil.

1576. Then would you go on to your next class of soil?—Yes, my Lord. Of course, we get an infinite series of gradations between that and the soil where you should draw the downward limit, and we usually regard clay soils as being at the other extreme.

1577. Yes?—That is to say when we get to a clay soil we know perfectly well that we have to limit our number of gallons per acre, or people per acre, very considerably. My experience with regard to clay soil has been mostly derived at Wimbledon, where I had charge of a farm for eight years, and that farm is 74 acres in extent. and I should say that 60 acres at least are pure London clay.

1578. Where was this at—Wimbledon?—Wimbledon. 60 acres, I should say, out of the 74 would be pure London clay; part of it, in fact, was an old brick-yard at one time before I adapted it to its present purpose. Now, on clay soils I have had experience in other parts, which I could give you if necessary—I do not know that it will be—but on clay soils the number of gallons per acre that you can purify depends entirely upon the depth of top soil. There is on every field a certain depth of top soil which is porous, and, therefore, contains vast numbers of the organisms which we know now are the agents which purify the sewage, and there is a rough sort of proportion which can be formed as to the amount of sewage which can be purified on clay soils by ascertaining the depth of the friable porous top portion. If, for example, the depth is six inches, it will purify about one sixth of the 30,000 gallons that I have already given you. that being one-sixth of three feet, and I put it in that way, because we know now that nearly all the purification that is done, even on porous soil, is done on the top three feet. If there is only four inches, then you can only put on one-ninth; if, on the other hand, you can do as we have done at Wimbledon, increase the porosity of the top soil to a depth of something like fifteen inches by the admixture

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of ashes, we put on an enormous amount of screened town ashes there, and we have got now about fifteen to eighteen inches of this very porous top soil, and as a result we can go up to 7,500 gallons per acre on our Wimbledon soil at the present moment. That I consider is about as far as we shall be likely to get, because we have to cease putting our ashes on the farm at Wimbledon, and burn our ashes in the refuse destructor, but I have no doubt whatever that if we did continue the system, and got a greater depth of this porous medium on the top we should be able to put on a larger proportion per acre.

1579. Do you consider there is no difference whether the land is grass or arable land?—I think that where you get anything like these quantities that I am referring to, 7,500 gallons per acre per day, the crops would be very much limited in character; you will be practically limited to rye grass, to mangels, and perhaps to cabbages, because of the large volume of liquid that is applied.

1580. What I mean is this, if you have arable land, the land is ploughed up every year, if you have grass land, the surface of the land is not disturbed?—Well, in the case of rye grass, we plough every other year.

1581. I see?—We sow, say, in the spring, and we get five cuttings the first year, and five or six, depending on the seasons, the second year, and then we consider that grass is worn out. We then plough in the winter, as a rule—at the commencement of the winter, and we allow the land to lie exposed to the influences of the weather all through the winter. In the spring we sow with rye grass again, or perhaps we change to mangels.

1582. You do not think that if it was left in permanent pasture the land would be able to take up as much sewage?—Oh, nothing like it.

1583. As it does, if it is ploughed?—I think about 3,000 gallons per acre—3,000 to 4,000 gallons per acre would be about the limit there, depending on the amount of surface soil you find there to begin with.

1584. Then in permanent pasture the amount would be very much less?—Much less. I might follow that remark by saying that I have observed with permanent pasture, where some large quantities of sewage have been applied, that the finer grasses are altogether destroyed.

1585. Are altogether destroyed?—Altogether destroyed, and in place of the fine grass, you get a coarse, rank grass, with an immense amount of coltsfoot, and so on. As permanent pastures, you may say, they are ruined the moment a large amount of sewage is treated there. I observed that more particularly at Warminster. I have, of course, observed it in other cases as well.

1586. Would you give us your experience of artificial filters, and as to their necessity, or otherwise?—Before we leave the clay soils may I say a word or two about the under drainage?

1587. Yes, please?—I should like to point out also that the slope of the surface has a good deal to do with it. I had one very troublesome sewage farm to cure. It was a great nuisance, and did not do its work properly; that was at Shepton Mallet, where the sewage farm was on the Kuyper Marl, which is practically clay, and there—I did not commence this work myself, the work of levelling—the farm was a long narrow strip, down the side of the valley, with a very steep slope indeed, and the effect of applying sewage to that very steep land was that it ran off the surface, without becoming purified. Well, then a large stone wall was built right down through the middle of the farm, just like a retaining wall, and that land was laid out then in two terraces, and the alteration of the slope there, combined with other works that were done, and improvements of various kinds that were carried out, had the desired effect, and that farm has been doing its work perfectly well since those alterations were made; so that the slope has to be considered. And then, again, there is another thing, which has been rather common, and even now I find in some cases, where I occasionally have sets of plans referred to me in competition schemes to report upon, that many of these plans have selected perhaps the only soil which is to be found, which happens to be clay, and many of the engineers who prepare these plans put in a number of under-drains. Well, if you want to ruin a clay farm, you can do it quite readily by under-draining it, because you cannot by any possibility convert an impervious bed of clay into a pervious bed by putting in under drains at intervals of half a chain or so apart. What really does happen in such cases is to cause the ground to crack even more so, far more so, in fact, than it would do naturally. The sewage then passes down the cracks into the sub-drains, and goes away unpurified, so that, unless you can do as we have done at Wimbledon to some small extent, and as has been done more recently at Leicester, unless you can bring those drains out on to the surface of your sewage farm lower down, where you can re-apply the sewage after it has come out of these drains, under-draining is a mistake in clay lands. If clay lands are under-drained, it should be done with the greatest of care, and places should be looked at where under-draining has been done, and the result very carefully examined into.

1588. Then you would condemn the under draining of clay altogether?—Absolutely, unless you can do as I say has been done at Wimbledon, and more recently at Leicester, where you put in a limited number of under-drains, bring the effluent up to the surface again on your own land lower down, and do not discharge it straight into a brook.

1589. That is not under-draining land where the effluent gets on to the land again?—We put the effluent on, and then if you happen to get—in some of those clay soils you get land that is not absolute clay—there is a certain amount of sand mixed with it, and it becomes perhaps changed into brick soil; in such cases as that, under-drains might be of service to you if the land has a tendency to remain wet, but even in that case, it is most essential that the under-drainage should be brought out at a lower point on your own farm, where it may be re-applied and finished—finished on the surface of the land lower down.

1590. Where it should be further treated?—It has to be finished, my Lord.

1591. Do I understand you to say that if you under-drain clay land the sewage will only enter the drain through the cracks in the soil?—That is so, unless the clay happens to be of a rather sandy character, when some of it might naturally filter.

1592. Of course, there are clays and clays?—There are clays and clays.

1593. Would you give us your experience of artificial filters, and as to the necessity, or otherwise, for clarifying the sewage before it is placed on the filters?—The first filters I made for the purification of sewage on a large scale were made when I was acting as resident engineer for Mr. Baldwin Latham at a sewage farm, where we made, I think, something like 25,000 square yards. At that time artificial filters were not perhaps as well understood as they are now, and we found a quantity of clay on the farm, which otherwise is mainly alluvium. We burned this clay in ballast, and then we sandwiched the soil; we formed there, with the burned ballast, in layers of about four inches in thickness, and built up our filters in that way. Those filters have done their work perfectly well ever since they were made, which was in 1880, but as they are not isolated from the other parts of the farm, the area is not defined, and, therefore, it is impossible to say how much those filters are capable of doing. They do pass a large quantity through; of course, we do not know how much. Well, then, when I came to Wimbledon, I began to make filters, and I made them of a great variety of materials. I made them of burned ballast, of clinker, of impure coal, which was known as bog cannel which, I think, came from Scotland, and I made them of some proprietary materials, which perhaps had better not be named; and I made them in a great variety of ways. I made some large wooden boxes, about one-two-hundredth part of an acre in extent, and filled them with these different kinds of materials, and applied crude sewage to them, and also clarified sewage. I also arranged some of the filtering materials, carbon—I forget the particular kind of carbon, but, at any rate, it was a form of charcoal, in vertical screens, in movable frames something like a window frame, with the view of taking out one screen, and washing out the suspended matter without taking away a very large proportion of the total area of the filters. That was for crude sewage, that particular form of filter, and, of course, the experiments showed that that particular way of dealing with crude sewage in filters was impracticable, because of the cost of cleaning the filters from the sludge, which accumulated in them, therefore, I devoted the greater part of my attention to filters, which were used for the purpose of finishing clarified sewage after it had been chemically treated. Having clay at Wimbledon, and having a restricted area of 74 acres, and a very rapidly increasing population, and practically no means of extending our area of land, we had to

get a substitute for the land, and we commenced to burn the clay in the filters. That has been going on since 1885, I should say, about, and we have at the present moment at Wimbledon something like 30,000 square yards of filters. We have sufficient material burned for another 10,000 square yards, so that altogether we shall have 40,000 square yards of these artificial filters at Wimbledon before this year is out, and we shall probably have to extend them in the future. We shall have to burn the clay, which will not purify as much sewage as these filters. We have not been able to arrive at any very definite conclusions as to the amount of sewage that these filters will purify from one year's end to the other, but I am not inclined to put it as high as perhaps we were led to suppose at one time we should be able to go. I think myself that the limit will be found somewhere at about 500,000 gallons per acre for that class of filter.

1594. 500,000 gallons per acre for that filter?—Yes.

1595. And is that as compared with 30,000 gallons per acre of the very best land?—Yes, I think, we can do 500,000 gallons per acre, but I am inclined to draw the limit at that.

1596. (*Mr. Killick.*) Is that clarified sewage?—That is clarified sewage after it has been treated with chemicals.

1597. (*Major-General Carey.*) About 100 gallons per square yard?—About 100 gallons per square yard is a very good figure.

1598. (*Chairman.*) And that is after the sewage has been treated with chemicals?—After, yes. I should say that we have one filter there which was made in 1876 which was originally 5,000 square yards in area, and that filter has been used for crude sewage, I think, since that time—since 1876.

1599. (*Mr. Killick.*) Continuously?—Continuously since 1876 for crude sewage only. It was made for two purposes. Originally it was made for storm water, partially treating the storm water when we got more liquid there than we could possibly put on the land, but it is also used for crude sewage in this way. Night pumping was not resorted to at first; they used to pump by day only. Then an overflow was put in the tank sewer, and at night, if the tank sewer became full, the crude sewage overflowed on to this filter. That went on, I think, until 1892, and during the whole of that time that filter bed received towards the latter end of the period every day a quantity, which we cannot very well ascertain, of crude sewage. Since 1892 we found that the overflow—rather in 1892—of this crude sewage every night was producing a nuisance, and we had to give it up. The filter is now very largely choked with the suspended matter. Of course, mineral matter must remain in the filter—when it once gets into a filter it must remain there; the organisms cannot touch the mineral matter. But there is the fact that that filter is very largely choked with the mineral matter which has got into it in that way. And I should like to point out that a smaller quantity of mineral matter has gone over with the sewage in that way than would have been the case if the sewage had been taken from the bottom of the sewer, because, of course, the heavier mineral matter keeps along the bottom of the sewer, and does not come out at this overflow at all. Well, then, in 1892, I think, it was, we started night pumping, and this particular filter has since only received crude sewage during periods of heavy rainfall, when the pumps have been unable to pump as quickly as the sewage has come to them. That is a very interesting example of the filtration of crude sewage.

1600. (*Professor Foster.*) When you compare the 500,000 on your filter with the 30,000 on the best land, you mean purified to the same degree?—I do, sir. Then when I went to the London County Council, in 1890, I suggested to the Chief Engineer, now Sir Alexander Binnie, that it might be desirable to make some experiments with artificial filters at the outfall works, and the Main Drainage Committee authorised the construction of some artificial filters, and I made four. Briefly, each filter was 1-200th part of an acre in extent. One filter was made of a proprietary material, one was made of burned ballast, as we call it, burned clay not of very good quality, one was made of pure coke breeze from the Beckton Gas Works, and the other was made of pebbles—small pebbles, small pea gravel rather—which we got from the Thames. I do not know that I need refer to those filters at any length, because the results have been very fully published, but the general result was that the filter made of coke breeze gave us the best results, and upon that the Committee authorised the construction of a much larger filter, and I then proceeded to make one which is generally referred to as being one acre in extent. It is really about 5,000 square yards. That filter was made of pan breeze, not with pure coke breeze, but with pan breeze, which is the cinder and other materials which are drawn from the furnaces under the retorts. It was broken down. And I foresaw a difficulty with regard to the working of that filter, having so large an area and having to be under-drained, and it was this, that, if we applied the sewage to the surface of the filter, having the outlet open as well, it would pass down through the coke breeze to the under-drains in a very rapid manner, and it would not become equally distributed throughout the whole body of the filter. Then came a question whether we could construct a whole network of distributing channels all over the surface? I found that would be very expensive, and I thought the easiest way, at any rate, of compelling every cubic yard of material to purify its right dose of sewage was to place a valve on the outlet and to charge the bed, and that is the manner in which that filter has been worked ever since it was started; and that is the reason why it was worked in that way. The results of the chemical analyses are given in those tables, and I think that it may be very safely assumed that a filter of that character would purify, continuously purify, about three-quarters of a million gallons per day. The effluent from the filter passes into a small artificial channel which we made, conveying it some quarter of a mile or more into an outlet where it passes into the Thames, and that I regard as being—that outlet channel—of very great interest, because it may be taken for granted that, where an effluent passes into a channel of that sort, which contains no other water, if it does not pollute its own channel it will not pollute the river into which it is discharged. There are limitations to that, of course.

1601. (*Chairman.*) Is the channel in the open air?—The channel is in the open air.

1602. And how long do you say it is?—Oh, I should say it is a quarter of a mile long.

1603. Then that effluent has simply gone through the filter?—That is a clarified effluent to begin with; it has been chemically treated.

1604. It has been chemically treated?—It has been chemically treated.

1605. Then through the filter?—Then through the filter.

1606. Then in a channel where there is no other water it passes into the Thames?—It gets into a channel, then it makes its way through the river outlet into the Thames. I have always laid very great importance, since I have become fully acquainted, of course, with the practical work of a sewage works, on an examination of the channel receiving the effluent. I have been to works—I went to see one work in particular, soon after a paper had been read describing in great detail the works which had been carried out, being a system of chemical treatment, followed by artificial filters, and a very glowing account it was, and there was a large number of analyses showing that the effluent was of a very first-class quality. I went to see the works, but I went to see something beyond that. I examined the channel into which the effluent passes for a distance of half-a-mile below the works, and that channel was simply in a filthy state.

1607. In a filthy state?—In a filthy state, showing that very small reliance can be placed upon chemical evidence alone as to the purity of any effluent in a case where the works are going on day after day and year after year. In every case, the most important examination that one can make is the examination of the channel which receives the effluent.

1608. Now that would bear upon land treatment. When you have simply land treatment have you examined the channels there?—I have, and if the Commission intend to visit works I should very much like to point out to them at Wimbledon the different degrees of pollutedness, so to speak, of those channels. We work our sewage in what we call three land treatment there, that is to say the effluent coming off the highest plot of all on the farm is applied again either to the next plot or to one lower down. It has either two or three treatments. And if you examine the topmost carrier that brings on either the clarified sewage or the sewage which, at Wimbledon (a part of it) is not chemically treated—brings either of those on

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you will find that that channel is, of course, polluted. Then you examine the next channel which receives the effluent from the No. 1 field, an open channel, and there the effect of purification is, of course, very marked; but after the sewage has been running, say, three or four days or more in that channel you will find probably growing together a green vegetable growth and sewage fungus side by side. Then you go on again to the next pick-up channel, and it is highly probable that in the next channel you will not discover any sewage fungus whatsoever if you look ever so carefully, and in the last channel of all you never see any sewage fungus at all in the Wimbledon farm.

1609. Do you mean that ultimately the effluent is absolutely pure?—Well, it is sufficiently pure not to pollute its own channel. Of course, we have had a number of analyses made showing that it is for all practical purposes a good effluent. We get no complaints from the Thames Conservancy Board, and it is really what would be considered a good effluent, but I hold the view subject of course to modification in certain cases, that if the effluent will not pollute its own channel it will not pollute the stream into which it is discharged, provided, of course, the channel is long enough to admit of these growths taking place.

1610-11. We are speaking now of raw sewage which goes on to the land, which is not treated chemically in any way?—Of both.

1612. I mean when you are describing your four channels?—We have both systems in operation at Wimbledon; we do not chemically treat the whole of our sewage.

1613. No, but you find that your fourth channel is not polluted?—The final channel?

1614. The final channel either by raw sewage or by clarified sewage?—That is so.

1615. Can you speak at all from your general experience as to the amount of purity attained in the average effluent from land treatment?—Well, I am generally called in where the farm is said to be a failure, and, of course, one very often finds that that is so. I have not the time, unfortunately, to go and visit farms which are said to be successful, and, as a rule, there is not much to be learned, but where one has to go, as a rule, to examine sewage farms is where they are a failure, and failures, of course, are due to a variety of different causes. One has to put them right. Badly laid down possibly in the first instance, possibly after they have been under drained, and are of a clay character.

1616. Your effluent has, I understand, to be treated in different channels before it gets pure?—Over three fields, my Lord, that is on a clay soil, where you rely upon the surface for purification. The usual practice is to apply it first to, say, field No. 1, then you catch it as it comes off that, and then you apply it to field No. 2. You catch it as it comes off that, and apply it to field No. 3, and provided each length of run is adequate the final result is good.

1617. Yes, but in most sewage farms would that be done do you think?—Oh, yes, that is the universal practice, in irrigation areas.

1618. You think it would?—I think so; other sewage farms are of a porous character. When I refer to those where the effluent actually goes through, it can only reappear from the subsoil drains, if there are any. In some cases, of course, there are no subsoil drains, it merely passes into the general body of underground water, and reappears in a natural way.

1619. Have you ever heard complaints of a sewage farm being injurious to health, either of individuals or of cattle?—I certainly have heard complaints in those very cases to which I have referred, where through either inadequate means of removing the suspended matter or through mismanagement or through the farms having been improperly laid out in the first instance a nuisance is created upon the farm, which is almost always due to suspended matter. In some cases it is due to the fact that more liquid is applied to the land than the land can take, that there is no proper interval of rest between the applications of the sewage to admit of the fields, putting it in the general phrase that you hear on sewage farms, "sweeten" itself. Some people say it has become sewage sick, but the meaning is exactly the same, it has not had time to sweeten itself between the applications of sewage, it becomes sewage sick. Then, of course, complaints arise, and it is mainly in those cases where, as I say, I am called in to advise as to the best methods of remedying the nuisance.

1620. Have you ever found cases where it was proved that it had done serious mischief to the health of either man or beast?—No, I have never found any evidence that could be absolutely relied upon in any case that I have been called in upon that would prove that.

1621. You were mentioning this pamphlet which you were good enough to send us. I see Mr. Roechling rather expressed some alarm about the notion of these artificial filters. "He thought it was very dangerous to "force the hand of nature, especially in a case where so "little was known about the very intricate processes by "which the decomposition of organic matter was brought "about, lest in this attempt they might create conditions "which in the end might prove disastrous." I rather think you were at the discussion?—I was at the discussion.

1622. Do you think that important?—No; I do not think so. We have to force the hand of nature at places like Wimbledon, for example, or we simply could not go on.

1623. Do you consider that there is a fair hope that by artificial treatment you will be able to get an effluent as good as you can get by land treatment?—I do not think there is a shadow of doubt about that, and I would like to try to make an explanation in this way. You examine any ideal sewage farm soil that I referred to first of all, there you find, perhaps 12 or 15 inches of soil, and the rest gravel and sand mixed. Now, if you dig out a cubic yard of that, and you re-arrange the particles, taking out the large ones and taking out the very small ones, I am quite positive that that cubic yard will do more work after the re-arrangement than it would in its natural state. I would try to illustrate my principle in that way, and if you substitute instead of your cubic yard of gravel, a cubic yard of other material which will effect the same purpose, you get this concentrated treatment, you can do more work, there is no doubt about it, by an artificial filter than you can on a natural soil.

1624. One witness whom we had before us said that, with any artificial treatment you would be forcing, that no artificial treatment was as thorough as land, because you could not force the thing through land, whereas you could force it through any artificial filter?—It is perfectly true that you cannot force it through land, but what he can do, and what is done in some cases, is to force the excess, which will not go through the land, into the river untreated, and that is where the trouble arises.

1625. Have you any remarks that you could make to us about the disposal of the sludge?—I have, my Lord, but there was one matter which I had in my mind a moment ago that I wanted to mention. I daresay it will recur to me directly. I know I thought it rather important. That, of course, is the most troublesome thing that we have to do with in connection with sewage disposal works, where the suspended matters are removed from the sewage to begin with. Of course, where there is a large area of land, which is of a suitable character, and remote from houses, the sewage can be applied as it comes from the sewers without creating offence, but that has been done for a great number of years at the Beddington sewage farm, for example, where no attempt is made to remove the bulk of the suspended matter. But even there, the time may come when they will have to remove the suspended matter, on account of the great growth of population which is going on at Croydon and the districts which drain to that farm. There are, of course, many other cases, but where the sludge is taken out by means of chemicals, and the population is at all large, and by large, I would almost go down to about 10,000 people as the limit, or even lower than that; I think it would be safer to go to 5,000 as the limit, the downward limit, undoubtedly the filter press should be adopted for dealing with the sludge. The usual practice where the filter press is not employed is to run the sludge into what some people call lagoons, which is a very misleading term. The beds are formed, as a rule, of town ashes, or any porous material that can be got, and the sludge is run into these beds in the hope that it will dry down, but if the quantity produced weekly is at all large, that system results in a great nuisance being produced. Then undoubtedly the proper way of dealing with sludge is to press it by means of filter presses. That was done, I believe, at Aylesbury in the very first instance. I cannot give you the date when the filter press was first employed there, but I believe that was the first case. I believe the Croydon Rural sewage works at Merton, on which I was engaged, to which I referred in regard to artificial filters, was the second case, and I believe Wimbledon was the third case in which filter presses were employed, and that is as recently as 1882, I think, at Wimbledon, but now hardly any sewage work is con-

sidered complete unless filter presses are employed for the purpose of dealing with the sludge. The operation of the press is, briefly, to reduce five tons of wet, sloppy, stinking sludge to one ton of cake, which can be handled, carted, and disposed of as soon as produced. There are cases, of course, where the larger limit of population is reached—London, for example—where it has been found undoubtedly that the most economical method is to pump it into steamers, and take it away to sea. I advised the Salford Corporation to adopt the same course, and they adopted my advice, and they take their sludge now down the Manchester Ship Canal, and discharge it into the sea beyond Liverpool. The Manchester works were brought into operation about the same time as the Salford works, and they adopted filter presses there, but, having seen the result of steamship carriage, they have now adopted at Manchester the same method of disposing of the sludge as at Salford; they have it shipped down the canal, and disposed of in the sea; so that, where the quantities of sludge produced are very large indeed, no doubt that is the most satisfactory way of disposing of it. It has a very low manurial value even after being pressed —very low. It is very rare to find sewage works where anything is given for it. In some cases, for example, Coventry, a very large accumulation took place around the works, and eventually began to smell rather disagreeably, and was complained of.

1626. May I ask if you are aware of Mr. Cameron's septic tank at Exeter?—Yes, I have seen that.

1627. You know that it is said that the sludge there largely disappears?—I have heard that.

1628. And Dr. Thomson, one of the Local Government inspectors, who held an inquiry at Exeter, told us yesterday that he thought that he might say he was surprised at the little sludge he found in the tank?—Well, one does not like to offer anything in the nature of a criticism of an experimental work.

1629. No?—But the only remark that I would like to offer is this, that those works have not up to the present time been carried on under the conditions that they would be carried on if all the sewage of any town, either Exeter or any town, was treated.

1630. You mean that it is on too small a scale?—What I mean is that the quantity applied to the tank, the quantity that can be admitted to the tank, is confined to the quantity that can be carried by a six-inch pipe, and, therefore, the vicissitudes that works are subjected to when you get sudden downfalls of rain, and so on, are not felt at those works, and therefore I am not inclined to regard at the present moment the results at Exeter as being by any means conclusive of the results that might be obtained if the works were arranged to take the sewage from the bottom of the sewer, and to take all the sewage that would be brought to the works under all conditions. If I may so regard it, it is something, in my view, at any rate, in the nature of a laboratory experiment.

1631. (*Mr. Killick.*) You spoke of the flow of sewage being divided into those cases where sewage and rain flow together, and where they were separated. Where the sewage and rain flow together, have you any opinion as to the increased quantity of the flow when the storm overflow should come into operation?—The point of cut off must be determined entirely by local circumstances. At Bristol, for example, where I have recently designed a scheme for the Corporation, I have arranged the point of cut off at five.

1632. Five times?—Five times, because the excess there will be discharged into a tidal estuary, but if the discharge were passed into a small stream of very pure water, I should place the point of cut off very much higher than that. In my own practice, I place the point of cut off at about eight or ten in such cases. Then, again, although it is usual to refer to so many times the dry weather flow, there is a better way of taking it than that, because the dry weather flow varies in many towns. The point of cut off should be arranged more with regard to a certain number of definite gallons per head. Where I take my point of cut off at five, I assume 150 gallons—five times the thirty. Thirty gallons being the dry weather flow, I assume 150 gallons per head at the moment the storm overflow is brought into operation. There, again, I think that the number of gallons should be considered rather than the number of times the dry weather flow. It is usually referred to in that way, but it very often leads to a wrong result.

1633. You would express the ratio then in gallons per head?—I would express the ratio in gallons per head, and the point to cut off should, as a rule, lie somewhere between 150 and 300.

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1634. In the information you gave us about the treatment of the clay at Wimbledon, by putting ashes—by covering the ground with ashes to the depth of fifteen inches, you could pass 7,000 gallons per acre per day over the land; that was really making it an artificial filter?—Making the surface of it an artificial filter.

1635. Exactly?—I may perhaps explain to the Commission the manner in which we applied the ashes. Before we applied ashes at all, we had to root up a large number of drains which had been put in, which caused our soil to crack before we adopted this method of improving the surface. At the time of ploughing, say, in the winter, when the fields are broken up, and the ground left open until the spring, before we did anything at all in the way of cultivation, we carted a quantity of ashes on to the land, on an average four inches in thickness. Then the ashes would fall down into this rough ground, and be worked up with it. Then, after two years, we would apply another four inches, and so on, until in the end we have got the depth of material, which I have referred to, but that is surface soil and ashes mixed together. The result has been, as you have described, an artificial filter on the top of the clay.

1636. You spoke of the filter that had been treated with crude sewage for something like twenty years; this filter, of course, has been cleaned many times?—It has been cleaned only on the surface. We find that, after a long period of dry weather, if we get a sudden downfall of rain, even a quarter of an inch of rain, it would wash out all the house drains, all the intercepting traps, all the sewers where you get a deposit; the result is to bring down to your works in a very short space of time indeed an immense amount of filth. That filth, of course, is intercepted at the top of the artificial filter, and in hot weather we have had to remove that after a day or two; when it becomes sufficiently solidified, we have had to remove that by hand labour, and dispose of it on the surface of our land, in order to avoid a nuisance.

1637. Has not the capacity of the filter decreased at all?—Oh, greatly. It is very largely completely blocked now, and we shall either have to regard it as being simply land, or dig out the whole of the material, and sift out all this mineral matter which has completely blocked it in parts.

1638. You spoke of failures which you are called in frequently to deal with—sewage farms which are failures. Have you taken any notice as to whether these farms have been in the hands of the authorities, or in the hands of a tenant?—Speaking generally, failures are more frequent where the farms are in the hands of an agent, than when they are in the hands of a local authority, who appoint their own manager. In the case of farms that are leased, the farmer naturally endeavours to make money. It does not follow that the making of money at a sewage farm at all agrees with the purifying of the sewage.

1639. When he has crops to rear, the sewage is turned untreated into the stream?—It may be turned either untreated into the stream, or it may be applied to land for too long a period, in which case the restricted area would not have effected its proper purification.

1640. Really there is little doubt that a sewage farm ought never to be let to a farmer, or pass out of the hands of the authority having it?—I am entirely of that opinion.

1641. Can you give us any information as to the cost of filters—of the best filters? You have described one, I think, at Wimbledon?—Those filters at Wimbledon cost us about £1,500 per acre. I should say that the burning of ballast usually costs about 2s. a cubic yard; if you have five thousand yards in an acre filter that is £500 for the ballast burning, the balance of cost being made of banks, under-drains, and so on. The London filter that I made, I think, cost about £1,700. I rather think the cost of that filter is given in the pamphlet. Then you come to what are known as proprietary filters, which are wholly enclosed in brick work, a form of sand and proprietary material. As a rule, those cost about £10,000 an acre.

1642. The proprietary material adding very considerably to the cost?—That, and the brick work, and valves, and so on.

1643. In this pamphlet you speak of the estimate for the Manchester filters—the estimate was £5,500 per acre; why is that estimate so high, do you remember?—Yes, it was in consequence of the very bad ground where the filters would have to be made

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1644. Clay?—No. It was more of that peaty character of land that is found in the neighbourhood of Manchester, and we thought that, in estimating for these filters, it would be necessary to do a good deal of concreting and so on. That cost, of course, is nothing like as high as the cost of the proprietary filters which you find in very many towns—that is, £10,000 an acre. The most recent example I have had of the price of filters is at Ilford, in Essex, where I have just made a contract of 6,000 square yards of those filters, which will cost £2,000.

1645. 6,000?—6,000 square yards will cost £2,000, but they are to be made in exactly the same way in which I made the London filter—that is, the ground will permit of this mode of construction being followed: we make an embankment all round and fill the interior with pan breeze.

1646. (*Colonel Harding.*) You spoke to us, Mr. Crimp, about the best kind of land for being able to deal with 30,000 gallons per day of clarified sewage. Can you form any opinion as to what would be the quantity that would be dealt with on similar land if you were dealing with crude sewage?—I think that would depend entirely upon the proximity of the farm to houses. I think if you attempted to put the crude sewage of a thousand to the acre there would be bound to be some smell, a smell probably that would not extend to a very great distance.

1647. But, apart from the smell, what would be the quantity of crude sewage which the best kind of land would be able to deal with?—I think it would perfectly well take the sewage.

1648. It would make no difference to the quantity whether it were crude sewage or clarified?—No; I think it would take the quantity quite well, but I do not think you would be able to put that quantity on without creating something of a nuisance.

1649. Then would there not be any necessity for periods of rest in that case?—Yes, and I have estimated that period in giving you that figure; that is to say, one acre of land—you could not put 30,000 gallons on it without giving it intervals of rest. You would have, perhaps, 60,000 gallons going on to it at the rate of 60,000 gallons per day for twelve hours, for example; the net result would be only 30,000 gallons for twenty-four hours.

1650. But would not the periods of rest be necessarily longer in dealing with crude sewage?—I think they would be.

1651. They would?—I think it is possible that the periods of rest required would limit the quantity. But what I think you would have to do would be this: where you apply crude sewage you have a perfectly plain flat surface, if it is on the downward filtration principle, but if you got to that large quantity, it might have to be applied after the removal of the suspended matter, which would involve chemical treatment which would not be involved in the other case.

1652. Am I right in understanding you to say that you could deal with as much crude sewage as clarified sewage upon a given area of land?—I think that is so; but more labour would be involved.

1653. Dealing now with cases where suitable land is not available, where, for instance, clay land only is available, I understood you to say that the action there was not so much the action of the clay land as of the soil over the clay land?—That is so; the whole of the purifying action must be in the top layer.

1654. So that the clay simply forms the bottom of the material which is dealing with the sewage?—That is so.

1655. You spoke to us of the possibility of improving that upper layer of light soil by adding to it, for instance, ashes, as was done at Wimbledon; by mixing that with soil you are still able to get crops?—Oh, yes, better than we did before, and we have also done this: Our land used to be known to farmers as "four-horse land," that is a phrase implying the employment of four horses in the plough; but now it is "two-horse land;" two horses can plough it quite as easily as four used to, the whole day.

1656. Have you at Wimbledon carried out the alteration of the upper layer of land by adding ashes to the point that you have ceased to be able to crop?—No; it is not so much that as the fact that the ashes are becoming a nuisance to us, and therefore we have to use a dust-destructor. They could go on, as far as I can see, applying the ashes for an unlimited period of time were it not for the fact that we cart our ashes down to the farm, and we cannot go on applying them day by day, as we carry them out there without laying idle a large part of the farm. We have to lay it out in the spring; that means taking the ashes to a depôt, and now the depôt is becoming rather offensive, and we have to go to the dust-destructor. But I am in hopes, and quite believe, that after we have our dust-destructor all the ashes that go through, with the exception of the large clinker, which probably will be used for road making, will be still spread on the land, and in that way we shall go on adding to our porous medium on the top.

1657. Then the action of land in purifying sewage is of the same character, is it not, as the action of an intermittent artificial filter?—Precisely the same action; the purification is effected as, of course, we all know now, by means of organisms which exist in vast numbers.

1658. Then, as Mr. Killick just now suggested, the improved surface at Wimbledon is in the way of artificial filtration?—I think it is a perfectly correct phrase to apply to it.

1659. Then it is an artificial filter from which you obtain crops?—That is so.

1660. Then by carrying the matter a little further you reach the artificial filter minus the cropping?—That is so again. You get to the point when your crops will not take the liquid that you have to apply in the case of concentrated filtration on an artificial filter.

1661. So that the relation of the artificial filter to ordinary land filtration is extremely close?—I think it is very close.

1662. I was interested by what you told us of the experiment upon crude sewage which has been carried on since 1876 at Wimbledon, and you told us that there had been a steady clogging up, which was largely due, in your opinion, to the mineral matter which had come down in the sewage, and which, of course, could not be broken down by the organisms. It would have been, would it not, fairly easy to settle that by passing it through some tank?—We should have had to construct rather an expensive work for the purpose, because of the levels.

1663. Apart from the mineral matter which is gradually accumulating there must have been a vast quantity of matters in suspension—sludge, in fact—to be dealt with in your filter. Have you formed any opinion as to how far that sludge has been destroyed or broken down by the action of the filter?—I think the organic matter has been entirely broken down.

1664. Then you do not think the sludging up has been due at all to the gradual accumulation of matters which it was possible to break down by the action of organisms?—No; the filter appears to be choked with a rich, black soil at the present moment. I have no doubt an analysis of that would show that it was rich in organic matter, but certainly not in the nature of being offensively so.

1665. Then what were the periods of rest allowed in connection with the treatment of crude sewage in that case?—Well, towards the end of the time, when we commenced our night pumping it would flow on probably at four o'clock in the morning and continue to flow on until about seven, and then no more would be applied, of course, until 4 o'clock the next morning. That was the usual, the average state of affairs up to the time when we commenced night pumping. Now, of course, it only goes over if we get a very heavy downfall of rain, which overmasters the pumps.

1666. Then does that mean that the filter stood empty for about two-thirds of the twenty-four hours?—More than that; it was from about 4 to 7. From 4 o'clock in the morning to 7 would be three hours; that would be one-eighth of the time; sewage was flowing on to it about one-eighth of the time, and standing seven-eighths.

1667. It was a continuous flow, not a filling and standing, but a continuous flow?—It was a continuous flow.

1668. And the flowing continued for three hours?—That is right.

1669. That, of course, is a very important experiment. If it was possible, by periods of rest, to digest sludge in artificial filters, that would be a very valuable solution for great cities, would it not?—Undoubtedly it would be, because where you apply crude sewage to land the soil digests the sludge, as we term it. Of course, the mineral matter is there. The only question that you would have to consider in designing works would be this: Is it cheaper to remove the mineral suspended matter by means of tanks; is it cheaper to remove that matter in that way than to allow it to flow into your filter, block it up, and then to sift your materials periodically?

1670. Not necessarily sift the material. Surely rest would be the equivalent?—No, not for the mineral matter.

1671. Not for mineral, of course not, but for the other matters?—For the other matters? I am quite satisfied that the organic matters would be broken up in the filter. Then, of course, comes size and cost, which is the cheaper, and you must expect also—I am bound to tell you this—that you must expect to pay. At this time of the year a heavy thunderstorm after a period of drought would produce on the surface of your filter a very filthy state of affairs in the absence of tanks, because your flow is probably increased ten or twelve times in the space of as many minutes. There is no control over that sort of thing; here this mass of sludge is deposited on the surface of the filter in the absence of tanks.

1672. Then, cost apart, you think it would be possible to digest the organic matters in suspension as well as those in solution in artificial filters?—I certainly think so.

1673. And probably you think it would be better to have some preliminary precipitation?—I certainly hold that view at present. Of course, as I have told you, I have had something like twenty years' experience of filters, and I see nothing to convert me to the view that it is best to run the sewage straight from the sewer on to the surface of the filter under all conditions.

1674. What would you think of natural precipitation as a first step?—I am very much in favour of natural deposition, more particularly when that is aided by means of a tank, a good many of which I have constructed. I did not design the original tank, but I saw that it did good work, that is a tank at Wimbledon, which was made in 1876, and I have used that very largely with excellent results, and I should like to put as shortly as I can what I consider to be the action of the tank. We know that if we take an ordinary sample of sewage and filter it through filter paper a clarified effluent is the result, and for all practical purposes it is as pure as an effluent that you can get by means of a first-rate chemical process, because, of course, it is now admitted by everybody that a chemical process does practically nothing beyond throwing down suspended matter. There is, I believe, a small reduction of organic matter, but in practice I do not think it is worth considering. I start from there then. I have my tank made; it is illustrated in my book on sewage. I do not know whether there is a copy here to show the Commission the kind of arrangement. But in the tank I place a bed of gravel, and I cause the sewage to flow upwards through that bed of gravel. In that way the mineral matters themselves are deposited upon the floor of the tank, and the organic matters, the floating organic matters, such as grease, and bits of excrement, and so on, that will not settle, are carried up into the body of the filter, and there they disappear; they do not come out in the end, and they do not remain in the bed of gravel; they disappear. I take it therefore that there is some agency there that perhaps I do not understand, but, at any rate, the suspended matter does disappear in the bed of gravel. Then the effluent, which is not as free from suspended matter as an ordinary chemical effluent, but more free from suspended matter than the London effluent—then that effluent is in a highly suitable condition for application either to land or to an artificial filter.

1675. Do you think that by natural precipitation you could get rid of such matters as fibrous matters, paper, tea leaves, and such like; would they sink naturally?—I think that would depend entirely upon the amount flowing through the tank, or the velocity. If it was a large tank with a low velocity, of course the matters which are nearly of the same specific gravity as the sewage or slightly greater would settle; in a small tank the same matters would be carried through without settling at all.

1676. Then you are of opinion that it is quite possible by artificial filtration to obtain good results if the area of the filter and the periods of rest are suitable?—Oh, there is no doubt about that.

1677. You spoke to us about the channels leading from the filters—the effluent channels?—I spoke confidently with regard to that, because I have had all these years' experience of it.

1678. Do you think it a wise thing to provide channels of that kind for the purpose of judging of the effect of the effluent on the stream before it reaches it?—No, I think not; I do not think so. I have known a case where a sewage farm was on the bank of a river; the river, I suppose, would be upwards of 1,000 times greater than the volume of effluent going in, and the effluent passed in that case straight from the under-drains of the farm into the river. Now, obviously in a case of that sort, the only means you have of ascertaining whether the effluent is good or not is to test it from time to time. That is one instance that I have in my mind where you could not apply that.

1679. But I am speaking of the effluent from artificial filters. I rather gathered that the condition of the effluent channels was a useful test of the efficiency of the work performed, and therefore I was asking you whether you would not consider it a useful thing before passing an effluent into a stream, whatever the stream was, for experimental purposes to have an effluent channel of a certain distance?—I think if that could be done it would be a most desirable adjunct to every filter.

1680. Then the presence of green vegetable growth without sewage fungus is a good sign in such channel?—I think that you may take it that if you find a channel containing sewage effluent only or sewage effluent mixed with a very small proportion of clean water, and you find no sewage fungus, that you require no better method of determining whether or not you have purified your sewage. I would rely upon that far rather than I would rely upon any analysis. And there is one thing about analyses that, of course, not being a chemist, I have not been able quite to understand. I told the Commission that if I filtered sewage through blotting paper I got clarified sewage, the same as if you treated it chemically, and you see on an average you would have, of course, a reduction of organic matter. I have some results in my book on sewage which I should have liked to refer to—comparative results—and the point that has always appeared to me to be rather a troublesome one to decide is this: If you take that effluent—we will say after you have passed it through the paper filter—and it is perfectly clear like that water might be (*showing with tumbler of water*) and free from suspended matter, and you mix with that five volumes of clean water, you reduce the albuminoid ammonia to what would be called a safe standard; but there is nothing more certain than this, that at the end of the week that would be a stinking liquid, whereas if you reduce that albuminoid ammonia to the same standard by means of artificial filters or land that effluent does not go putrid. But both the waters have the same amount of albuminoid ammonia to begin with; therefore I do not think that chemistry tells us all about the subject.

1681. That was rather the point that I wanted to get at. You have spoken to us about the presence of green vegetable growth in the channel as being a good sign?—That is so.

1682. Then suppose the channel were so banked up that some water remained in it to a certain depth always, and that it was possible to have fish living in the effluent, if fish could live in the effluent, that would be a still better sign?—Well, it would certainly be as good; I do not know that it would be better. I think the other is an extremely good one.

1683. The vegetable?—Of course, where you have fish living another question comes in which may or may not apply in the case of the vegetable growth. Probably the thing I have in my mind may be common to both. You cannot have fish in an effluent water unless you have oxygen in the water, and I do not quite know how the oxygen gets in in all cases. I know in some cases, where there is plenty of leakage in the sewers, there is dissolved oxygen in the sewer when it comes to the work.

1684. Then do you find that they are able to live in a very impure effluent?—I think they must have oxygen. It is more a question of oxygen. I have seen fish in the river, for example, dashing in and out into the most filthy sewage, where they remained until they get their particle of food that they saw there, but they instantly afterwards came back into the water which is charged with oxygen.

1685. The point I wanted to get at rather was: You told us the difficulty of estimating results merely by chemical analyses?—Yes.

1686. I wanted to find out whether by means of an effluent channel it was possible to have physiological tests; that is, tests of vegetable growth, and tests of animal life?—Yes.

1687. Which would be useful in judging of the results of either land or artificial filtration?—And you would substitute the fish for the green growth?

1688. No?—If you find them both there, as a matter of fact.

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1689. Yes, that is so?—If you put the fish there the green growth would grow all the same.

1690. If you found green growth and fish living in such a channel, would you be able to conclude definitively that that effluent was not unsatisfactory?—Undoubtedly.

1691. Then as to the depth of filters. Have you in your experience formed any opinion as to the depth of filters?—You spoke about the small thickness of soil at Wimbledon, six inches I think you said, over the clay?—Yes.

1692. And you said that the effect of land did not go beyond three feet in depth?—About three feet; that is, organisms have not been found at a greater depth as a general rule.

1693. Have you any experience to show how deep artificial filters may safely be made if made of suitable material?—Four feet in depth. My experience leads me to three feet as being the best depth. I have gone to four feet, but I am making them three feet as being a more satisfactory depth.

1694. Can you tell us where we could see any examples of modern developments in artificial filtration besides those which are quite familiar to us at Sutton and Barking?—Have you seen the Barking filters?

1695. You were telling us about the Barking filters?—There are the Wimbledon filters, the filter at Barking, and there is a very interesting filter indeed made by Mr. Baldwin Latham at Friern, Barnet, because there the filter has been in operation for a number of years, since 1886, I think, and the effluent at this time of the year is going into a stream that is practically as small as itself, so that the effluent is subject to a very severe test there, and that filter has stood the test of time. I think it would be very interesting for the Commission to see that filter.

1696. Do you know of any others which it would be interesting for us to see—typical cases?—Of course, there are lots of proprietary filters, as they are commonly called, but no doubt you will see some of those. There are cases, of course, where these filters have been given up altogether after being in use for some time.

1697. (*Dr. Russell.*) In putting crude sewage on land would there be the same tendency to chokage with mineral matter as in the artificial filtration?—Oh, no, sir; in the case of artificial filtration it is concentrated upon a small area; in the case of land it is spread over an extremely large area.

1698. And more or less by agricultural operations also?—And then the agricultural operations are carried on which cause the mineral matter to be mixed with the soil.

1699. Would you explain how it came about with this slope in the case of that clay land you mentioned materials that it proved inefficient for purification?—Because the sewage which was applied of course at the top of the land ran with great rapidity down the slope and into the river before it had time to be brought into intimate contact with the top layer of the soil.

1700. What would be the depth of the top layer in that case?—It was very thin; it certainly was not more than about five and a-half inches on an average.

1701. Then you have told us after doing the very best you can with clay soil, that you can only get one-quarter of the work out of it that you can out of the best soil available for land filtration?—That is so.

1702. And enormously less than you can get out of an artificial filter?—Unless we went on with our amplification of ashes to build up the layer of filtering material and the clay to a greater depth. I have no doubt if we went on for a number of years and eventually got as much as three feet of this porous material on the top of the bed of clay that we should be able to purify a larger volume of sewage than we are able to at present.

1703. But I thought you said that the highest point that you thought was obtainable was about a quarter of what good soil would give?—That is with the thickness of material that we have got.

1704. Fifteen inches?—About fifteen inches, but I do not see anything to prevent if we continue the process of gradually building up with greater depth of filtering material. I do not see any reason why the population limit should not increase. As a matter of fact it has increased from about 100 per acre up to 250, and I do not see why if the process was continued it should not go on still increasing with a greater depth of filtering material.

1705. Is it likely that it would reach the efficiency of the best available natural soil?—I believe it would eventually, because that would mean that your original seven or eight inches or whatever it may have been of surface soil had been gradually worked into your larger amount of material of a highly porous character. It would lose itself; in short, the fine surface material would lose itself as it were in the more porous material that you put on.

1706. These facts make it evident, do they not, that there must be cases of large populations situated in the middle of clay land where the land treatment is an impossibility?—If the area of land is limited, undoubtedly you must supplement the land by means of artificial filters.

1707. That very interesting observation you make about the condition of the channels, I suppose that could be followed up and made a subject of laboratory observation by taking samples and keeping shallow vessels in circumstances corresponding to the conditions of the channel?—Certainly.

1708. And observing what happened?—That has been done. We have done that at Wimbledon in this way. We have taken samples from the channels, say the first channel, the second channel, the third channel, and the fourth, and of course there is a gradual increase in the amount of purification effected until when you come to the fourth channel there is the effluent that is really what would be termed first-rate effluent, incapable of producing any mischief in the river.

1709. In that way you would test something which mere statement of chemical analyses does not give you: that is to say, the stability of the effluent?—Precisely.

1710. (*Professor Foster.*) I think you said that putting aside the choking by mineral matter and the nuisance which might arise to habitations, that your good land would take equal quantities of crude sewage and clarified sewage?—I believe that to be the case.

1711. Does that mean with the question of the land there is simply the passage of the fluid and not the removal of the impurity to be considered, because with the crude sewage there is more impurity to be removed, is there not?—Yes; it is this, that the amount of liquid that you have determines the period of rest that you have to give to the land; that is to say, the land becomes sewage sick, not because of the small amount of suspended matter that you have carried out with the sewage, but because of the amount of liquid. I have known land to be sewage sick that has been treated with clarified sewage that contains no suspended matter whatsoever beyond perhaps one or two grains per gallon, yet that land has become sewage sick.

1712. May I take it the great thing is that the land should allow the water to pass, being quite sure that if that water does pass the objectionable things will be removed?—That is my view.

1713. And I suppose in the case of crude sewage having a large quantity of solid matter in suspension—of decomposable matter in suspension, the destruction of that takes place on the surface really?—It does.

1714. And sewage sickness with you is saturation of the soil with water—clogging with water rather than any stoppage?—Oh, undoubtedly. I have known the very worst case of sewage sickness I ever saw—it was absolutely cured in three days after the sewage was diverted from the field—three days afterwards it had completely recovered itself.

1715. Clogging with water and not simply a stoppage of organic changes?—Oh no, simply that the—well, I suppose, to put it in familiar language—organisms must have been drowned in the soil; at any rate, they could not perform their functions.

1716. How do you judge of the purification which has taken place by the land method?—Personally, if the stream is a small one I invariably inspect the stream. If the stream is a very large one relatively to the amount of effluent we merely have to rely on the chemical analyses.

1717. Of the drains?—Of the effluent water.

1718. But in the case of land the effluent there would be in drains, would it not?—It would be in sub-drains probably, not necessarily, but probably. But whether it is in sub-drains or whether it is in open channels at

the surface, if it passes into a very large volume of water probably a chemical effluent without any land treatment could not produce a nuisance.

1719. I was rather thinking of what you said, that with your artificial filter you could bring 500,000 gallons per acre to the same degree of purity as you could your 30,000 gallons on land?—Yes.

1720. With your artificial filter you have your effluent there which you can regularly test; it passes from below the filter?—Yes.

1721. On your land you take the effluent from the subdrains?—That is so.

1722. And your view is, I understand, that a physiological test, such as that of the appearance of what you call sewage fungus, is far more trustworthy than any chemical analysis?—I think so undoubtedly, and I had rather an interesting experience in that connection in 1880, I think it was, or 1882, where an action was brought against the Croydon Rural Sanitary Authority, which has been reported, and in that case the effluent water coming from the farm when analysed appeared to be extremely pure from the albuminoid ammonia point of view and so on, but it contained large quantities of sewage fungus, and the sewage fungus settled in a pond at the point where the effluent pipe discharged into the Wandle. There was a large backwash that had been scoured out. The sewage fungus settled in that pond and formed an extremely offensive deposit. The consequence was that the riparian owner has obtained an injunction against the authority. The case, of course, is reported in the Law Reports. That bears out what I say, that you cannot regard chemical analysis as being conclusive evidence of the purity of an effluent.

1723. I rather gather that in the case of some of these channels the sewage fungus did not make its appearance at the commencement of the channel?—No.

1724. But later on, after a quarter of a mile or so?—The sewage appears to be too strong—the crude sewage—to grow fungus.

1725. I am speaking of the effluent from the filter?—Oh, it will appear immediately at the exit.

1726. Immediately?—In many cases you see it outside, actually growing on the pipe, and perhaps into the pipe which discharges the effluent into the stream. I noticed that at Horsham, where the artificial filters failed. There the stream from the point where the effluent pipe entered it, down for a considerable distance, there was an immense amount of sewage fungus, and it was actually growing in the pipe which discharged the effluent into the stream. I have also seen it in other cases.

1727. But have you in your experience met with cases where an effluent channel of some length exists and the effluent appears to be free from what you call sewage fungus as it issues from the filter, but appears later on?—The only case I know of is that Croydon case, and there was a man-hole on that effluent channel about half way down its length—the effluent conduit, rather.

1728. That is a closed effluent, not an open channel?—A pipe, that is. That is of considerable length, and there was a manhole on that about half way down its length, and I examined the manhole, took off the cover, and went down, and the sides of the channel there were simply a bed on which the fungus was growing. It was obviously growing in the effluent pipe, the same probably as it was growing in the drains under the land itself.

1729. And I think in your works at Wimbledon you said that in one of the effluents—the one which had only been partially treated—you have green conferval and sewage fungus growing together?—That is so, in what we call the second run of sewage.

1730. So that the green conferval can grow readily in the effluent which is so little purified that it bears the sewage fungus?—It certainly did not grow readily; it seemed to be a struggle. The point perhaps had arrived when the very strongest specimens of this growth were just able to survive. I should rather regard it from that point of view.

1731. (*Professor Ramsay.*) I did not quite clearly catch whether in filtering through good soil taking 30,000 gallons a day, you filter intermittently?—Yes.

1732. For how long is the liquid run on to the soil, and for how long is the soil allowed to remain at rest?—Well, practice in that respect varies with the rapidity with which the soil can dry itself, but I should say the usual practice would be to run it on for perhaps from three to six hours, and then allow it to dry off during the remainder of the twenty-four hours.

1733. Are there any manufacturers at Wimbledon; are you bothered with trade refuse?—No; ours is entirely domestic sewage, and is supposed to be the easiest sewage to treat. And that reminds me of what I wanted to remember before the adjournment, and that is, at Wimbledon at this time of year, when there is no water in the subsoil at all, which helps to dilute the sewage, our sewage goes down to about 22 gallons per head per day. It is in a very concentrated form. The number of people living at Wimbledon, of course, is the same as the number when we have 30 and 35 gallons per head per day. The result of that is that our sewage is extremely offensive, and we have to deodorise as well as precipitate, which is a most important distinction. I have not known any other case where it has been necessary to do that, but at the present time we have to use a very much larger dose of chemicals in treating our sewage than would be necessary if we simply had to throw down the suspended matter.

1734. And what do you deodorise with?—We deodorise with lime, and, as a general rule, sulphate of iron, and when the state of affairs gets very bad we have to use permanganate of potash as well.

1735. And do you find that the permanganate has any influence on the filter beds?—No; not the least.

1736. I suppose the colour goes very readily?—It goes instantly.

1737. (*Chairman.*) Can you say whether it produces any effect on the effluent in the channels—the deodorisation?—Well, I do believe this, that the more chemicals you use in precipitating the solid matters the more difficult it is to purify that effluent afterwards. I have always noticed that in our high level sewage at Wimbledon, which is strained in the manner in which I explained to the Commission before the adjournment, that the effluent from those filters is more readily purified on the land than the effluent from the other part of our system, where it has been chemically treated. Whether it is that we leave in the natural agencies that tend to purify sewage, or what it is, I do not know, but I do know that that sewage is more easily purified than the sewage that has been chemically treated, that is the final purification.

1738. (*Professor Ramsay.*) Another question I should like to ask has reference to the ashes. You say that your ashes are increasing in your hands, and you require to use a dust destructor?—That is so.

1739. Is that material which is left after the dust destructor has been used of use for the soil?—Yes; that material is of two classes. In the first place, you get large clinkers, and in the second place, you get a quantity of finer material, which is practically of no service as it is fine ash, and so on. That I intend to have used on the land at Wimbledon.

1740. The fine ash?—The fine ash. And after we start our destructor and we get some clinker I shall have the clinker broken down to a small size, and make some experimental filters with it, and the chances are—of course, I do not see any reason why that should not be a good material—the chances are that we shall be able in that way, instead of having to go on burning clay at a great expense, to use that material for our filters as we require to extend, because I have found in my experience with filters that it is not so much the kind of material you use for your filter as the size of the material.

1741. The porosity?—The size of the particles forming the filter.

1742. The porosity?

1743. (*Professor Foster.*) The character of the spaces between?—The character of the space between.

1744. (*Professor Ramsay.*) Are those ashes of any use for crops; do you grow good crops?—Oh, we get magnificent crops.

1745. But it must contain a great deal of carbon, surely?—No doubt.

1746. Coal refuse?—Yes, no doubt; but the crops that we get there seem to be of the most luxuriant character.

1747. Then when you prepare the clay soil, as you apparently do there by putting ashes on the top, does the water run through the ashes and then over the clay, or is there any soakage into the clay?—I think

Mr. W. S. Crimp, M.I.C.E.
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the soakage into the clay—the clay you may take it is impervious, absolutely impervious. I do not believe that the clay underneath the top layer does the smallest bit of good in the way of filtering the sewage at all; I do not believe the sewage ever gets into it at all.

1748. Then is any attempt made to mix the ashes into the clay by ploughing or trenching?—Yes, we plough the land in the winter every alternate year; we plough with a very large plough, which leaves the land very rough. Then in the spring we spread our layer of ashes over, and then that is worked in by the ordinary methods of cultivation in preparing the surface for its sowing of rye grass or mangels.

1749. So that really a considerable proportion of the clay gets brought to the surface and mixed with the ashes?—Well, I think we have got beyond that state now. We have got about fifteen inches of this material there, and our plough does not go down more than about eight inches, so that I am quite sure we never reach the clay at all now with our ploughing.

1750. Is it possible for an effluent to be satisfactory near the filter, and yet to putrefy after some time, after it has flowed some distance?—Chemical effluents will undoubtedly do that unless they are passed into a very large volume of water, but I am quite sure that good land effluent would not do that, or a good effluent from filters.

1751. You spoke of the advantage of connecting the filters with the river by means of a fairly long channel; at all events that point was mentioned?—The advantage in my mind was more from the critical point of view, to see whether the work you were doing was really good work, not the question of chemical analysis; although if you are conducting a sewage work on a moderate scale you cannot go to a chemist with a sample of the effluent every day; it would be simply ruinous.

1752. But would it not be possible for the effluent to run out from the filters in such a state that no change would take place, and that no change would take place then until it reached the river?—I do not think that any change does take place in the good effluent; I simply say that I regard that as a satisfactory method of ascertaining whether or not you have done your work properly.

1753. Yes, but my point is this, that even supposing you had a bad effluent you would not discover it, because no change would necessarily take place in that channel or conduit which connected?—Yes, you would get your conduit full of sewage fungus then.

1754. (*Professor Foster.*) That was my point, whether with a very short conduit, a very short channel——?—You would get sewage fungus at once.

1755. You have not met with a case of filtrate effluent which appeared to be perfectly good and free from the so-called sewage fungus at its issue, and continued so for some little time along the channel, and then eventually developed it?—No; sewage fungus begins at once.

1756. (*Chairman.*) There is one question about which I do not feel quite clear. Do I understand you to say that you consider the underdraining of clay land is no use at all, except for the purpose of carrying the fluid somewhere else?—The underdrainage of clay is a mistake if it is clay pure and simple. If it is clay that some people would call "sandy clay"—and some people would call it "clayey sand," according to their taste—then, of course, an underdrain might be of some use if you got a patch of that sort of stuff where water would tend to lodge, wet places on your land, you might say, "I will just put a drain in there to run off that water." But I do not think in that case you should allow that water to discharge into the stream; you ought to run it out into the surface of the land lower down, or leave it on the land.

1757. I do not quite understand. The underdraining of clay might be good if you could do like you did at Leicester?—At Wimbledon, for example, our farm has a slope like *that* (*illustrating*), and then we get down to a part where it is much flatter. We have a few underdrains. I told the Commission that we took up a very large number of underdrains there altogether that were damaging the farm. These drains do not discharge into the river, but they discharge into a carrier on the farm, and the effluent coming out of those drains passes into the carrier, and is re-applied to the land lower down.

1758. Yes, quite so. But then the effluent from the point it enters the drain to the point at which it comes out of the drain undergoes no change?—I do not know. The water that comes out here from these underdrains—we have a very few of them, but the water that does come out of the underdrains is very much better than the crude sewage that goes on.

1759. Well, but then is not that rather against your argument, that it is no good to underdrain clay?—Then I say that where we have done this it is not what I call "pure clay"; it is more of what you might term "brick clay."

1760. But you would condemn underdraining in pure, stiff clay?—Absolutely. I know for a fact that it is a great mistake to put a single underdrain under very stiff clay.

1761. (*Major-General Carey.*) If sewage can be applied to a sufficient area of suitable land, do you consider that that is the best, and the most satisfactory means of dealing with it?—Yes.

1762. In preference to any other?—I prefer that to any other.

1763. You would adopt that mode of treatment in preference to artificial filtration?—I invariably recommend all the authorities I am advising—if I can find a suitable area of land I invariably recommend them to go to it in preference to any other system.

1764. It is only in a case where the land is totally unsuitable, as in clay land, that you recommend artificial filtration?—No, I should not recommend artificial filters, because the land in the neighbourhood was all clay. I should first of all look at the land, and I should ascertain the quantity that one could procure; then I should look at my population, and I could then ascertain whether the population was likely to increase, and if so, to what extent. Then I should put all the facts together, and having considered the matter from that point of view, I should decide whether I would recommend the authority to take the clay soil, or adopt a chemical process and filters.

1765. As to the maximum portion of 30,000 gallons of sewage per acre per diem that applies to the specially prepared land to which artificial filtration is compared?—That is so.

1766. Not to broad irrigation?—Oh, no.

1767. Can you give us in that proportion of gallons of sewage per day that ought to be applied on broad irrigation farms?—I should certainly not go for ordinary broad irrigation—I should certainly not go above 5,000 gallons per acre per day unless the circumstances were extremely favourable, and I think it would be more prudent under average conditions to limit this to something like 3,500 gallons per acre per day.

1768. About 100 population to the acre at 30 gallons a day?—It would bring you down to somewhere about that.

1769. Somewhere about that?—Yes.

1770. And as I understand the maximum of 30,000 gallons per day is a maximum under any conditions?—Under any conditions.

1771. Any possible conditions?—That is so. If you were to say what area would you require for a certain population under those circumstances with a flow of 30,000 gallons per day, I should know perfectly well that if the dry weather flow were 30,000 gallons per day the average flow for the whole 365 days would be about from 20 to 30 per cent. in excess of that because of the rain. There may be leakage from the soil and so on. Then I should say I want to provide for that by adding to my area something like 20 per cent. to provide for those conditions.

1772. For the storm or rainfall?—Yes.

1773. That is to be included in the 30,000 gallons, the amount of drain water that you are going to treat at your works?—Yes, and in dry weather you would be probably applying something like 25,000 gallons per acre per day; you have got then a little margin for the wet.

1774. As to under-drainage, you are of opinion that there ought to be no under-drainage of clay subsoils. Does that apply to ordinary subsoils or more suitable subsoils, or do you think there might be under-drainage under any circumstances?—I think on porous soils, whether under-drainage is required or not, would depend entirely upon the line of saturation. You will find in some cases in valleys where there are plenty of mills, for example, that you can get a plot of land. You make your examination, you find it is extremely porous, you find you come to the subsoil water, say at two feet. Well, you want more than that; you want to lower your subsoil water then by going below perhaps the first mill, and bringing up a subsoil drain into this very porous formation, you might lower your subsoil water to the extent of four or five or six feet, and in that case you are doing good work. You do not want, in that case obvi-

ously, a general system of under-drainage; all you want to do is to lower the line of your permanent saturation to the extent to which you wish to go, which is probably limited to four or five feet.

1775. That is a case where the subsoil is to a certain extent waterlogged?—To a certain extent waterlogged.

1776. You want to reduce the subsoil water. I am now assuming a case where there is no subsoil water, where you simply have an area of prepared land in which to apply the sewage, say at the rate of 30,000 gallons per acre, without subsoil water, perfectly dry to a depth of six feet; would you under-drain it?—No, I should not put any under-drains in there.

1777. In none of those cases?—No.

1778. You would not under-drain them except where it was desirable to lower the level of the subsoil where there is subsoil water and you want to lower the level of it?—That is my practice. I simply take the view that you cannot convert an impervious into a pervious material by putting down a few drains underneath it.

1779. But I am assuming that the whole subsoil is pervious?—I go upon that principle as regards the clay, and then I say, as regards the others that are really pervious, you might add to the depth of your available filtering material in some cases by lowering the subsoil water, and that you can accomplish by a very moderate amount of under-drainage indeed.

1780. As to artificial filters, do I understand that if the area of filters is sufficient to fill at the rate of 500,000 or half a million gallons per day that you consider that the same results as regards purity would be obtained as from suitable land?—I think that is so.

1781-2. But not with a more restricted area?—No.

1783. If you were to double the quantity—a million gallons—you would not produce the same results or the same successful results?—No, the quality of the effluent would fall off.

1784. It is of first importance that the area of the filters should be sufficient in any scheme of artificial filtration that the area of the filters should be sufficient at that rate, the rate you mention, and not above it?—That is most essential; I would not certainly go above it, as a general rule.

1785. In order to produce a first-class effluent?—No.

1786. And then there is the question also of management. I presume that in any scheme of chemical treatment and artificial filtration first-rate management has to be exercised throughout?—It has.

1787. Both as to the nature of the chemicals to be used in the chemical treatment and also in the management of the filters?—That is so. I have often found when I have had charge of works and visited works, you find the manager for some reason, he takes a glass, and he sees that the effluent looks bright, and he thinks that it is all right. There is a great disinclination on the part of managers to aerate their land or their artificial filters, as the case may be, sufficiently. They think very often, as it is coming through bright and clear, that that is the chief object they have to accomplish, forgetting, of course, that although it might be bright, it may still contain a very large amount of putrescible organic matter, and that is the great lesson that these men have to be taught, and it is one that they are very slow in learning, and that is, the constant aeration of their filters or their land.

1788. You cannot always, of course, as a rule, rely upon having that management, first-class management, and supervision?—No.

1789. Therefore it does afford a certain objection, I suppose, to the use of artificial filters—the difficulty of obtaining the first-class management and efficient supervision as against land, which perhaps might to a certain extent take care of itself?—Well, I am afraid that unless they manage the land properly, and unless they manage the filters properly, they will get bad results in both cases.

1790. With regard to storm overflows, I understand you thought that five times dilution—that is to say, assuming the daily consumption to be 30 gallons per head—150 gallons should be the minimum passing through; that is to say, you would let the rest pass off by the storm overflows?—Yes, I think that unless the circumstances are quite exceptional that the line should be drawn there.

1791. That would be the safe minimum?—Yes, I think so.

1792. Then that 150 gallons would have to be treated, would it not?—The 150 gallons you have remaining in your works would have to be treated at your works. But I do not think the cut off ought to be lower than 150 gallons per head per day.

1793. At any rate you would have to make provision in your scheme for that margin?—Yes.

1794. In addition to your ordinary sewage—dry weather flow?—Certainly. In making experimental filters, for example, you get a certain result in the laboratory to a square yard of filter, as I think the first Royal Commission did, but you cannot rely upon doing exactly the same thing when you come into work, because your conditions are constantly varying. It would be very much like pouring on your water with great care the exact quantity to be applied, the exact time, and then in the middle of it somebody comes and jogs your elbow, and instead of getting the amount, you get twice as much. Then, of course, the man would say, "You have spoilt that experiment altogether," and that is just what you are getting in reality at the works. You are constantly getting this tipping out of this very much larger quantity than you get under average dry weather conditions.

1795. To go to bacterial filters, have you tried bacterial treatment at Wimbledon?—Well, of course, we have about 30,000 square yards of filters.

1796. Yes, I know?—And we use them intermittently, and no doubt the purification is effected by means of organisms. We certainly have not called them anything but filters, but I suppose they are really bacterial filters.

1797. You do not allow the same intervals of rest as they do at Exeter and Sutton; there is no regular period of rest after the filter is full, for instance?—We are working our filters at Wimbledon now in the same way that I started the large London filter, and for the same reason, that I do not quite see in a large artificial filter, 5,000 square yards in extent, for example, how you can make every cubic yard of material do its work, and no more than its work, and the whole of its work, unless you do it in that way. You can possibly do it with a whole network of distributing channels over the surface, but I do not see that there would be anything gained by such a network; of course, it would be much more expensive than the very simple way that I adopted there, and which I have carried out since, of throttling the outlet, and allowing the effluent to remain in contact, say, two hours, then draw that off so that the filter gets thoroughly aerated before you resume it. That is really why that was done. In very small filters, of course, it is very much easier to wet the whole of the surface; in very small filters you can do it, but when you come to large filters, an acre in extent, it is extremely difficult in my view to make every cubic yard do its own work in any other way.

1798. (*Colonel Harding.*) You were speaking just now about the necessity of good management in land filtration and artificial filtration. Does bad management of a filter—if a filter becomes thoroughly choked and foul in your experience, do you find it necessary to renew the material, or will rest accomplish the restoration desired?—That depends entirely on whether it has become choked with sludge containing a lot of sand, or whether it has simply become choked.

1799. I am assuming that the choking is not due to mineral matter?—Then I think— in fact, I am quite sure that the filter would recover itself if it is not due to mineral matter.

SEVENTH DAY.

Tuesday, 18th October, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S
Professor WILLIAM RAMSAY, F.R.S.
Major Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.

Mr. F. J. WILLIS, *Secretary*

Mr. W. S. CURPHEY, F.I.C., F.C.S., called in; and Examined.

Mr. W. S. Curphey, F.I.C., F.C.S.

18 Oct. 1898.

1800. (*Chairman.*) Mr. Curphey, you are, I believe, Her Majesty's Inspector for Scotland under the Alkali Acts and the Rivers Pollution Prevention Act?—I am.

1801. And would you tell us what former offices you have held?—I had no official appointment previous to being assistant to Dr. R. Angus Smith. I studied chemistry previously to that. I have been Inspector under the Alkali Act, since 1882, since the Act of 1881 came into operation.

1802. And under the Rivers Pollution Prevention Act?—Since 1895.

1803. Is the Inspectorship under the Rivers Pollution Prevention Act always held by an Inspector under the Alkali Acts?—It has been so in Scotland.

1804. And do you think that is a good arrangement?—The duties of an Inspector under the Rivers Pollution Prevention Act of Scotland are not very heavy; they are not sufficient to occupy the time of an official fully.

1805. Do the Inspectors under the Rivers Pollution Prevention Act make regular reports?—No, they do not; that is to say, there are special reports after every inquiry, but no regular general reports.

1806. Could you give us in outline the duties of the Inspector under the Rivers Pollution Prevention Act, and give us a general idea of how the Act is managed?—So far as the duties of the Inspector are concerned he has no initiative whatever; he makes no inquiry unless directed by the Secretary for Scotland; the Secretary for Scotland takes no action in the matter until he has been approached by a local authority or by a private party seeking to induce action by a local authority. When he has been approached he may direct the Inspector to give him further information if that be required. The custom has been to make what is called an informal inquiry; he visits the factories and places complained of, sees the complainants, and also the people complained against, generally takes samples of the river affected, and subsequently reports to the Secretary for Scotland. The Secretary for Scotland then considers his report, and acts as necessary under the circumstances. The Inspector has no further duties after submitting his report.

1807. Is the number of cases in which the Secretary for Scotland has been appealed to large?—Not at all numerous, considering the number of streams polluted.

1808. Have you any theory to account for this comparatively small number of cases?—The initiative is left very much in the hands of local authorities. I am not prepared to say altogether what circumstances influence their action. Sometimes the authority itself is an offender and cannot be expected to take a very active part in preventing pollution. Action is very likely to be hampered by inefficient jurisdiction; there may be authority over a small portion of the stream only, and it is no inducement to attempt to deal with the question in a piecemeal manner. In the case of the Clyde there has been a good deal done, I understand. The Clyde is perhaps in an unusual position in this way. Above Glasgow it is all situated in the County of Lanark, therefore the jurisdiction is not subdivided; it is a populous district, with considerable industries, and the question of pollution is more prominent than in many rural parts of Scotland, where the population is sparse and the industries very limited. In Fifeshire also the County Council have been endeavouring to bring the Rivers Pollution Prevention Act into operation, but for some reason—I cannot say the reason—it has not actually taken definite shape.

1809. How many inquiries have you yourself conducted since you became the Inspector?—There have been thirteen.

1810. And how were they started?—In eight cases the sanitary authorities under the County Council sought power under Section 6 of the Act to take proceedings against manufacturers for pollution; in four cases private individuals who considered they had reason to complain of pollution, and had approached the Local Authority unsuccessfully, sought directions from the Secretary for Scotland to induce action on the part of the local authorities; and in one case a sanitary authority wanted more time to develope a scheme for purification under Part two of the Act with regard to Sewage Purification.

Since 1886 the following enquiries have been made:—

Stream.	Initiator of Enquiry.	Nature of Pollution.
Gala	Private Party	Dyeing and wool scouring.
Ruthven	" "	Dyeing.
Allander	Local Authority	Sewage and manufacturing.
Lochs Long and Goil.	Private Parties	Solid matters and sewage.
Leven (Dumbartonshire).	" "	Dyeing and calico printing.
Gareloch	County Council	Sewage.
Doon	—	Tar and sulphate of ammonia manufacture.
Irvine	—	Sewage.
Leven (Fifeshire)	County Council	Sewage and manufacturing.
Tweed and certain tributaries.	" "	" "
Kilbirnie Loch	" "	Tar and sulphate of ammonia manufacture.
Clyde and certain tributaries.	" "	Coal washing.
Clyde	" "	Tar and sulphate of ammonia manufacture.
Niddrie Burn	Private Party	Sewage and paraffin oil manufacture.
Devon	County Council	Sewage and manufacturing.
Duntocher Burn	Private Party	Sewage.
Clyde	County Council	Coal washing.
Don	Private Parties	Sewage and manufacturing.
Tay	County Council	Sewage.
Spey and certain tributaries.	" "	Distillation of whiskey.
Medwyn (tributary of Clyde).	" "	Paraffin oil manufacture.
Tyne	Private Party	Sewage and tannery.

1811. Are you in favour of having any fixed standard of impurity for sewage or trade refuse?—Not one standard to be of uniform application. I think local circumstances influence the question too largely.

1812. Will you give us your reasons why you would not have a fixed standard?—The position of the works on the streams is one point—at the works situated high up on the stream where the river may be in its natural condition—the manufacturer has purer water to work with, and if a standard of impurity be fixed he has a certain margin within which he can work, and still not exceed the limit. The manufacturer below him has a less pure water and a narrower margin to work in, and as you come down the stream it may be that the lower manufacturers would have to return the water as they get it. Then there is a great difference in the quality of the effluents from different manufacturers. Some are more easily purified than others, and would more readily comply with a standard; some are more noxious than others. If a standard be made for general application it must be sufficiently lenient to allow these effluents which are difficult of purification to comply with the standard. In that case the standard is unnecessarily lax, for those waters which are readily purified. Then improvements may be made any day, as this is a question which is attracting a great deal of attention. A standard which may with difficulty be complied with now may, with improved methods, become a very low standard indeed. Present experience points out how methods have advanced. Making a standard sets up a limit beyond which advance is discouraged, because a manufacturer will not seek to do more than the standard

requires. I might refer to the valley of the Spey. The manufacture of whiskey is an industry which has increased very rapidly in that district during the last few years. It was formerly more limited and partially spread over agricultural country. By means of feeding cattle, etc., and by land irrigation the liquid products were disposed of. Now that the industry has expanded so greatly, the waste liquids are no longer sufficiently disposed of by these means, and some of the tributary rivers are very much affected. I know of no suitable method for satisfactorily dealing with those liquids under all the present circumstances. It is a question of very urgent local interest. Proceedings have already been taken, in the Court of Session, under the Common Law of Scotland, and a County Council has moved in the matter under the Rivers Pollution Prevention Act. Distillers say that they are desirous of doing what they can. A number of them have joined together, and have offered a premium of £2,000 for a suitable method of dealing with waste products. They had called in experts previously, but these have not been very successful. I might submit a copy of the conditions which are attached to this premium of £2,000. They are as follows:—

The Subscribers whose names and designations are printed on the second page hereof, hereinafter called "the Combination," hereby offer a premium of £2,000 to a person devising and handing over to them for their sole use and behoof such a scheme for treating the bye-products of Distilleries as will effectually purify them and be adopted by the Combination, and that on the following conditions, viz.:—

1. The money shall not be paid

(1) Unless and until the Combination are satisfied, by practical tests carried out by themselves or others authorised by them, that the scheme proposed satisfactorily treats all bye-products of Distilleries, and for this purpose competitors shall be bound to place their scheme, if required, at the disposal of the Combination to be experimented upon by them, with the assistance of the Competitor, either on a large or small scale, and that for a period of one year from the time the scheme is placed at the disposal of the Combination, or such longer or shorter period as may be agreed upon.

(2) Unless and until the Combination are satisfied that it can be accomplished at a cost which in the opinion of the Combination is reasonable.

2. Should two or more equally effectual remedies be devised by two or more different persons, the Combination shall have the power of deciding to whom the premium shall be awarded.

3. The power of selecting the persons who shall compete shall be in the absolute discretion of the Combination.

4. Samples of the bye-products will be placed free on rail to any person or persons the Combination may approve.

5. The premium shall not be paid unless and until the scheme is handed over to the Combination and vested in them as their absolute property.

6. All questions or differences arising between the Combination on the one hand and a competitor or competitors on the other hand, whether as to the meaning of these presents or any other question or difference, shall be settled by the Combination, who appoint themselves as sole arbiters for this purpose.

I agree to compete on the foregoing conditions.

DISTILLERS FORMING THE COMBINATION.

Thomas Yool and Company, Miltonduff Distillery, Elgin.
Glenlossie-Glenlivet Distillery Company, Limited, Glenlossie, Elgin.
Gordon Smith, Gragganmore Distillery, Ballindalloch.
Glenmoray-Glenlivet Distillery Company, Limited, Elgin.
Craigellachie-Glenlivet Distillery Company, Limited, Craigellachie.
Benrinnes-Glenlivet Distillery, Limited, Aberlour.
Dailuaine-Glenlivet Distillery, Limited, Carron, Strathspey.
Imperial Glenlivet Distillery Company, Carron, Strathspey.
North of Scotland Distillery Company, Carron, Strathspey.
Tamdhu Distillery Company, Carron, Strathspey.
Geo. and J. G. Smith, The Glenlivet Distillery, Glenlivet.
Parkmore Distillery Company, Dufftown.
George Cowie and Son, Mortlach Distillery, Dufftown.
Glenfarclas-Glenlivet Distillery Company, Ballindalloch.
John Walker and Sons, Limited, Cardow Distillery, Craigellachie.
R. Thorne and Sons, Limited, Aberlour-Glenlivet Distillery, Aberlour.
Balmenach-Glenlivet Distillery, Limited, Ballindalloch.
The Speyside Distillery Company, Limited, Kingussie.
Linkwood-Glenlivet Distillery, Limited, Elgin.
Glentauchers-Glenlivet Distillery Company, Mulben.
William Teacher and Sons, Ardmore Distillery, Kennethmont.

Bearing on that point, if the standard was fixed such as these people could comply with just now, if this premium were to do any good, or if subsequently some large improvement were made, they could go very much further than a standard fixed to comply with present knowledge.

1813. Do you think that in particular instances fixed standards could do any good?—I think it is a very convenient thing in certain circumstances. In Scotland there have not been many cases of the kind; I know of only two that are now in operation. One is in connection with the manufacture of paraffin oil on the River Breich. Dr. Stevenson Macadam and Professor Crum Brown many years ago were fixed by the Court of Sessions as the officers to inspect these works; standards were fixed, and they have been complied with, I believe, ever since. They have been found very useful for letting the manufacturers know how far they had to go and what was considered practicable under the circumstances. Again, in the case of the River Esk, which is polluted by paper manufacturers, an official was appointed by the Court of Session to inspect the waste effluents, but there the standards are not so definitely fixed; they are matter of mutual agreement between the official appointed by the Court and the manufacturers, and they vary with the different factories. Paper-making effluents vary very much in impurity, and under these conditions the standards are also altered.

1814. Have standards been fixed in connection with the Alkali Acts?—With regard to atmospheric pollution, yes. There has been a gradual devolution, one might say, with regard to those standards. The Act of 1863 only stipulated that a certain amount of the muriatic acid gas should be condensed; a certain amount—five per cent.—was allowed to escape. There were no conditions fixed in the first Act with regard to the manner in which this escape was allowed; it was allowed to escape in any way, dilute or concentrated; it was sufficient if 95 per cent. was condensed. After some years' experience, there was another Act passed, in 1874, eleven years later. In it the amount of muriatic acid was limited to an escape of 5 per cent. of that evolved or to 0·2 grain per cubic foot of air, smoke, or chimney gases—it was no longer allowed to escape in a concentrated form. The best available means were to be used to prevent the escape of noxious gases other than muriatic acid. Another Act was passed in 1881. It made no alteration as regards the escape of muriatic acid, but the gases from sulphuric acid manufacture were brought under a limit, viz., acidity equivalent to four grains of sulphuric anhydride per cubic foot. At this time also a number of other works were brought under inspection, chemical, manure, and various other works. For these no standards were fixed; they were to use the best practicable means. In 1892 another Act was passed, extending the scope of the Act and bringing some other works under inspection, but the question affecting the limits of escape was not alluded to in that Act. So there has been no change since the Act of 1881 with regard to standards.

1815. Do you think, speaking generally, that the best practicable means of obtaining purification of effluents are generally adopted?—No, I do not think so.

1816. Do you think more inspection is required?—Yes. I think inspection is quite as important a point as provision of means of purification. The provision of the means is certainly necessary, and it is necessary that those means after being provided should be kept in operation. I do not think there is any guarantee that that is so, unless independent inspection is provided to secure it.

1817. What would you say ought to be the units of

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the various administrations?—I think the river basin; the main river with its tributaries should be the unit for administration. These river basins also, I think, should be under inspection, either after the manner of inspection which obtains in the Mersey and Irwell and the West Riding of Yorkshire, or after the manner of inspection which obtains under the Alkali Acts, where the inspectors are appointed to certain districts. It would also be a great advantage if these district inspectors were to report to a chief inspector or district boards to a central board, where the work done, the advances made in any district could be focussed and reported upon collectively, so that any improvements which were made in any particular district would be available for the general advantage and general adoption all over. I think it would be a great advantage if the knowledge and experience which is daily accumulating were collected in an accessible form and made generally available.

1818. Would you have an inspection of the rivers independently altogether of the local sanitary authority?—I think that is most desirable. The sanitary authorities of Scotland at present have a great deal to do with the operation of the Act; where they are actively disposed a great deal may be done, but where they are indisposed they form a very serious obstacle to the adoption of the provisions of the Act. I might call your attention to a report of my predecessor, Mr. Fletcher. He had occasion to visit a small stream in Perthshire which had been complained of. Application had been made to the Secretary for Scotland to call upon the Sanitary Authority to take action against certain works which were polluting the stream; they had refused to do so at the request of a private party. Mr. Fletcher went down and reported. He confirmed the existence of pollution, and suggested means for minimising this pollution, and reported to the Secretary for Scotland. The Secretary for Scotland addressed a direction to the sanitary authority of Aberruthven that those suggestions should be enforced. But under Section 6 of the Act the Sanitary Authority has the option of reconsidering the question, and deciding whether it will put into force the direction which is sent by the Secretary for Scotland, and in this case they declined to do so, and the provisions of the Act were rendered quite inoperative.

1819. Have you anything you would like to say as to any general conclusions?—The general conclusions that I have come to are that I do not think it is desirable to define rigid general standards of purity. Standards may be formed for local circumstances but not for general application. I do not think it is desirable to fix any particular method of purification as the best; circumstances vary so much. I think it is desirable that the actual and continued use of the best practicable means should be ensured by inspection, and that it is also desirable to collect and render accessible the experience and knowledge which is daily accumulating and will continue to accumulate with regard to preventing pollution. I might hand in four reports; I should perhaps have said that four reports have been issued. (*Reports handed in.*)*

1820. Are these under the Rivers Pollution Prevention Act?—Yes, they are under the Rivers Pollution Prevention Act.

1821. And these are the only four?—They are the only four, and they are not continuous.

1822. (*Mr. Killick.*) In your opinion very little progress has been made in Scotland for the enforcement of the Rivers Pollution Prevention Act of 1876?—I think very little progress has been made.

1823. And you attribute that to the sanitary authorities containing interested parties?—That the stream above and below is polluted and the difficulty of proving pollution in their own area.

1824. But you attribute it to the authorities containing interested polluters?—They may have; that was not exactly what I meant to convey. Very often the sanitary authority as a body send the sewage into the streams. I have no doubt that interested polluters have some influence, but how far that influence extends is not very readily proved.

1825. Also you say that the stream above and below is polluted, and there is difficulty in proving pollution within their own area?—No; what I wished to convey was that a sanitary authority with a limited jurisdiction might endeavour to purify a certain section of the stream, but action in that case was discouraged because their operations would only affect a small part.

1826. And therefore you recommend committees or authorities for the whole of the basin or, as we say, the watershed?—Quite so.

1827. And that authority you think should be a combination of local authorities or a Government authority?—Personally I am inclined to a Government Department, which would be more powerful according to my own experience, but the advance which has been made in the Mersey and Irwell and the West Riding point to that also being a very suitable method of dealing with the question.

1828. In Scotland the counties have a concurrent jurisdiction over the rivers with the local sanitary authorities?—I am afraid I do not quite grasp that.

1829. In England the county and the local sanitary authorities have control over the streams; is that so in Scotland?—Could a county deal with the whole of a stream by itself as well as the local authorities could deal with it?—The County Council is practically the sanitary authority.

1830. Where all the stream is in a county the County Council could deal with it?—Quite so, yes.

1831. Where the stream is in more than one county a combination of County Councils could deal with it?—Yes.

1832. And apart from Government inspection that would be the best authority you think?—I think so. I may say that in connection with the pollution of the Tweed there was an endeavour made to come to some understanding between the county authorities and urban authorities of Galashiels and Hawick, but unfortunately my official position does not enable me to know what was the course of events, but nothing came of their communications with one another; they could not come to any understanding.

1833. Supposing watershed committees were formed of the county or counties covering the watershed area and each authority in the watershed committee had a right of appeal to the Local Government Board, would not that bring in the Government control which you desire?—Supposing there is a committee of more than one county dealing with a stream and the duties of the committee were neglected; if any constituent authority—any county—could appeal to the Local Government Board to step in and see that the work was done, would not that provide the Government control which you desire?—The initiative would still lie with the local authority, would it not?

1834. That is so; but with any local authority if there were more than one?—The difficulty in Scotland is that the local authorities do not seem to have acted.

1835. You think that would not be sufficient?—I am inclined to think not.

1836. (*Dr. Russell.*) The illustrations of the establishment of standards that you gave were with reference to paraffin works and the paper mills and polluted streams; those were instituted after an inquiry in the course of an action at common law?—That is so.

1837. So that as regards these particular offenders they were put under exactly the system which you would think ought to be instituted by some general law?—Yes, that is so.

1838. The result of the action went so far as to appoint in some cases an expert chemist, and in other cases an expert engineer to take charge of the particular works or set of works and to see that the standards instituted by the Court were enforced?—Quite so.

1839. You think that that ought not to be left to the accidental raising of actions, but ought to be made automatic for the whole country by some general legislation?—I think so.

1840. A similar system?—Yes.

1841. Of course you do not come here as a lawyer, but I do not think the Commission have heard anything about the Salmon Fisheries (Scotland) Acts, and simply to get it on our notes I would ask you, are you aware of the existence of such Acts?—I am aware of the existence of such Acts, but I have no practical knowledge of their application at all. There is an official who is inspector under that Act. Until lately it was Mr. W. E. Archer, who was inspector under the Salmon Fishery Board, and he was recently appointed Inspector of Fisheries to the Board of Trade, and a successor to him was subsequently appointed by the Fisheries Board of Scotland. He no doubt

*The Reports are as follows:—(1.) Report to the Local Government Board, by Dr. R. Angus Smith, F.R.S., 1882 (C3080). (2.) Second report to the Local Government Board, by Dr. R. Angus Smith, F.R.S., 1884 (C4085), on the examination of waters. (3.) Report to Her Majesty's Secretary for Scotland, by Alfred E. Fletcher, Esq., F.C.S., F.I.C., 1888 (C5346). (4.) Report to Her Majesty's Secretary for Scotland, by W. S. Curphey, Esq., 1898 (C8847).

is familiar with the Acts; I am not in a position to say anything.

1842. You know in general that they include references not only to mechanical obstruction in the shape of weirs but also to the introduction of poisonous and injurious matters into the rivers?—That is so. The Fishery Board approached the Secretary for Scotland some time ago with regard to the pollution of the Don in Aberdeenshire, and I believe they are still taking measures in regard to that.

1843. Commissioners selected from the proprietors along the banks constitute a Board; perhaps you are not aware of that?—I am not aware of the working of the Act.

1844. (*Professor Ramsay.*) I should like to ask when the Alkali Acts of 1863, of 1874, and subsequently of 1881, came into operation—was the standard rigidly enforced from the very beginning?—There was a good deal of latitude allowed at the beginning until manufacturers had experience in dealing with the question. There was a good deal of latitude allowed when the endeavour to comply was genuine. That with regard to myself is wholly a matter of information; it was long before I was connected with the administration of the Acts in any way.

1845. But since your time, which I think dates from 1881?—Yes.

1846. Have the Acts been rigidly administered as regards the total amount of gases escaping and so on?—Not rigidly; accidental matters are overlooked.

1847. Do you not think it would be possible to lay down some sort of system of standards for sewage on the understanding that it would not be rigorously enforced from the very beginning, but, as it was in the case of the Alkali Acts, be left greatly to the judgment of the inspectors; there appears to be an advantage in having an ideal to aim at?—That seems to discount to some extent the standard if it is left to discretion.

1848. But we are agreed that in the Alkali Acts the standard was discounted in the same way?—Yes, that is so.

1849. Any sensible inspector would not unduly press a manufacturer?—Quite so.

1850. Do you not think that standards for sewage could be worked in somewhat the same way?—My experience of sewage of late years has not been extensive. When I was referring to the standards I was thinking more of manufacturing pollution which has come more frequently under my observation. With regard to sewage, it is perhaps in a different category from trade effluents, and a standard might possibly be of use there, but I think even there it should be administered with a good deal of consideration.

1851. Could that be reached by each Board for itself; could they lay down certain regulation to apply to certain rivers in their jurisdiction which would act as standards practically for their districts?—I think the focussing of the experience in different districts would be of great value in that direction. The experience in one district might serve to enlighten the experience in another district. I think it is a matter that should be gradually arrived at—the question of standards. I think at present we could scarcely ask for so much as after some years of experience and education of the manufacturers.

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1852. (*Sir Richard Thorne.*) The same idea that was embodied in Professor Ramsay's questions was passing through my mind, and it was this: Would it, in your opinion, be possible, in order to avoid the difficulty of one fixed standard, that river boards should be allowed to make a scale of standards, and apply one or other according to differing circumstances within their area, according to their judgment, subject to an appeal to a central authority?—I think it would be a difficult matter to draw up varying standards of that kind.

1853. The question is one, I admit, that is involved in difficulty all round, but what is the meaning of the "best practicable means" except a sliding scale standard?—Well, that is what it comes to. One great advantage of the "best practicable means" is that you do not lay down any limit.

1854. No, but it involves taking every case into Court to prove that the best practicable means has been adopted, whereas the onus of proving that would lie rather upon the manufacturer, who, for his own interest is polluting the stream, if he objected to any one standard that the Rivers Board imposed upon him?—It would, no doubt, be a very much more simple thing if there were standards; it is a much more onerous position to take to have to decide on the best practicable means, but I think at present the question of standards would be difficult to define, as I said before.

1855. May I ask you whether in your reports with regard to pollution of rivers, you adopt a standard for your own purpose?—Well, that question has only arisen with regard to coal washing, where suspended matter was the chief impurity.

1856. But have you in your mind a standard below which you would advise the State to take proceedings?—I am not prepared to give any standard.

1857. Would you tell me if there is a standard applied for the purpose of the Fisheries Board of Scotland?—I am not at all acquainted with the workings of the Fisheries Board.

1858. I gather that you are very strongly of opinion that the duty of initiating proceedings against the polluters of rivers should be taken away from the local authorities, and should be given to River Boards or some similar body?—I think so; I think the great weakness of the present Act is the want of initiative on the part of the inspector; he can do nothing.

1859. I suppose Scotland is not very different from England in this respect, that when a man wants to avoid being interfered with in certain things, such as the pollution of a stream, he often gets elected as a member of the body that has the power of initiating proceedings?—I suppose it is not unknown.

Mr. DONALD CAMERON, City Surveyor, Exeter, called; and Examined.

1860. (*Chairman.*) You are Mr. Donald Cameron, the City Surveyor of Exeter?—Yes, my Lord.

1861. And an advocate of the septic treatment of sewage?—Yes.

1862. Would you give us a short description of the objects of those methods of sewage disposal?—The aim I had in view was to bring the sewage into such a condition by arresting the solids in suspension as to make the filtration on artificial filters practicable; at the same time taking advantage of the solvent action that goes on in the arrested solids, so as to make the quantity of deposit or sludge as small as possible.

1863. Would you give us any description of the experimental tanks and filters used at St. Leonards in Exeter before the construction of the present works?—The first tank that I had of any size was in part of the public grounds, or an addition that was made to the public grounds at Belmont, in Exeter. It is a small tank, dealing with the sewage of about thirty houses, including a reformatory. The tank was 12 feet by 15 feet and by 2 feet 6 inches in depth, containing about 3,200 gallons, and the quantity of sewage flowing per day was at the rate of 3,700, or a stay in the tanks of about 20 hours. In this tank very little deposit at all was found in the bottom, but a very large thickness of scum formed on the surface of the water. The next tank was at Belle Isle, close to the works, which some of the Commissioners have seen, and it was for the purpose of showing to the Corporation what could be done by this system of disposal. The tank was designed to deal with a quantity of sewage ranging from 7,500 to 10,000 gallons per day, the sewage being abstracted from the St. Leonards sewer. The capacity of the tank was 6,300 gallons, and the stay in the tank, therefore, was at the rate of from 18 to 20 hours. There were no filters attached to the first tank at all. I filtered the effluent from it through small sand filters, and I found no difficulty in dealing with it in that way. To this first tank at Belle Isle were attached two filters, each with about an area of 24 square yards, or combined the 1-100th part of an acre. The filtrant in these filters was composed of coke, small coke, as it came from the gas works, thrown in, without any screenings or siftings, and covered over on the top by a layer of limestone chippings. The rate of filtration after the filters were some time at work was from 150 to 200 gallons per 24 hours, or at the rate of 510,000 to nearly 1,000,000 gallons per acre per day. As the result of the working of this installation, the Council decided to construct larger works sufficient to deal with the whole of the flow of the St. Leonards sewer, so as to be able to show to the Local Government Board the system in practical working. They felt that it would be unfair and useless to submit to the Local Government Board a scheme of this description on paper only.

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1864. And then would you next give us the nature, the quantity, and the flow of the St. Leonards sewage?—The sewage conveyed by this sewer, as judged by the quantity of oxygen consumed in four hours at ordinary temperature, Mr. Perkins, the Public Analyst, found to absorb 3·158 grains per gallon. I, unfortunately, could not lay hands on Dr. Rideal's report, and I am unable to give you the figure. Dr. Dupré found it to be 4·266 grains per gallon; Messrs. Dibdin and Thudichum 2·028, and Messrs. Pearman and Meor 4·30. I may say that it was desired by the Corporation that we should be able to deal with the sewage from the city, in which was trade refuse, but no place could be found in the city to lay down works that would do this—lay down sufficiently large works to do it—and the distance to Belle Isle was too great for the outlay. But I consider the average sewage of the city, that is the trade and domestic sewage combined, to differ but little from that of St. Leonards. In this case I have only got the domestic sewage. St. Leonards has no earth closets or privvies in it; it is altogether a water closeted district, and the water supply is about the rate of 25 gallons a head. The distribution of the flow of sewage is shown by this curve. (*Tracing produced.*) That curve was plotted from gaugings taken over the 24 hours in 1895—near the end of summer, 1895, I think in July, and that gave a quantity of 31,250 gallons per day as a maximum dry weather flow of sewage. Subsequent gaugings at the end of the drought of 1896, and after a defective brick sewer had been taken up and a pipe sewer laid down, showed the flow to be at the rate of, in round figures, 35,000 gallons in 24 hours, the distribution being practically what is shown upon that curve. The curve shows that for the five hours at night from half-past one till half-past six in the morning, there is practically no flow, only the leakage from the water taps, or about four gallons per minute, and that the bulk of the sewage passes from half-past six in the morning for 16 hours afterwards. At half-past ten in the day it rises to a maximum of a little over 56 gallons per minute, that is, at the rate of 81,000 gallons per 24 hours, and that was the figure adopted in designing the works; that was the proposed quantity that the works should deal with.

Appendix No. 14 (A).

1865. Will you tell us what provision you make for the storm water sewage?—In this case in order to avoid any obstruction to the flow of the sewage to the tank, and so as not to have a valve or pen stock, which if shut down partially, to regulate the flow, would inevitably keep the floating particles from getting into the tank. I had a pipe laid at such a gradient that it would convey 125,000 gallons per day to the tank, and the only provision made for the storm water was for the difference between the normal flow of sewage and this quantity of 125,000 gallons. As a matter of fact, only 122,000 gallons ever came to the tank. That is the biggest record that we have got. I should say that the storm sewage question is, I think, of any the most difficult to deal with.

1866. I am not sure that I quite follow you. Do you mean that a storm water overflow has never been necessary?—Oh! no, my Lord; any quantity over and above the 122,000 gallons went by storm overflow—which I shall describe further on—into the river. I should like to say first something on the storm water question. At present the provision made for storm water is by allowing in the sewers for a quantity of rainfall equal to one-quarter of an inch spread over the 24 hours, one-quarter of an inch of rainfall. In Exeter this would mean, with the area that we have got to deal with, five times the normal sewage. The quantity over and above this flow, that is, ¼ of an inch per 24 hours at maximum flow of the domestic sewage—anything over and above that goes by storm overflow into the river or into the streams. These storm overflows come into action according to the rate of flow of sewage in the sewer. I think regard should be had to the fact that it is not so much a continuous provision for storm sewage that is required as an arrangement whereby the first washing from the street and sewers could be conveyed to the outfall works. If that were obtained, if that first wash could be secured and prevented getting into the water courses, it is not of so much importance that the remainder of the storm water should be kept out. For instance, such a day as we had yesterday, after the heavy rain of the morning, in the afternoon the storm water would not be so polluted as at the beginning of the heavy rain. In order to obtain the first washings from the town I would rather propose or suggest that storage should be provided at the works, into which the sewer would discharge, and when the storage is nearly used up, that it should bring into operation a storm overflow. Whenever it is full up it should cause the surplus storm sewage to overflow by storm overflow outside the works. Such a condition, of course, could be devised after it has passed through the tanks, but I think it would be preferable to have it before it enters the tanks. Under these conditions a storm overflow could be provided that would be independent of the rate of flow in the sewers, and only come into operation after the first great wash from the town has been provided for.

1867. Would you tell us the means used in intercepting sewage to the tank?—In order to get the sewage containing all the solids that the sewer had brought along, I had the main sewer, which previously led into the river, cut across 8½ inches below the invert, and the pipe from the tank was led away from this cut; at the same time I had a weir put in the invert of the sewer on the down stream side of this cut, so as to give a head of 16½ inches on the drain leading into the works. Any quantity of storm water over and above what the drain can carry goes by that storm overflow or by that weir into the river.

1868. And the means used for arresting the detritus carried down by the flood waters?—(*Plan put in.*) On plan the sewer or drain leading to the tank is divided at a manhole into two branches, each branch leading into what I call grit chambers. On the section above is shown these grit chambers in longitudinal vertical section, and the inlet pipes from the sewer are conveyed half way down, or five feet below the surface of the water into these chambers. Up till July, 1897, that was the only provision made for arresting the detrital matter or the grit. After the visit of General Crozier in June, 1897, I put a small grit chamber on the drain as it comes out of the main sewer, and whenever that had to be cleaned out, the contents were stirred up till there was nothing but detrital matter left, and that taken away and kept. From that period that grit chamber has arrested all the heavy gritty matter which has come down.

Appendix No. 14 (B).

1869. (*Professor Ramsay.*) Which is that—is it M H on the plan?—It is beyond that; it is further up in the Lane. As the drain comes away from the main sewer; it is a very small pit, 4 feet by 1 foot 6 inches by 4 feet deep. I may say that considerable difficulty was found in getting the solid matter, especially the fat, into this drain. I devised several means, covering it over with an iron plate bent to the section of the pipe, but the fatty matter caught under the iron and accumulated there. What I have now done is to invert a funnel-shaped or a trumpet-shaped form to the mouth of the drain, whereby all the fatty matter and any matter stirred from the bottom drops into the drain and is carried to the tank.

1870. (*Chairman.*) Would you give us a description with the dimensions of the tank itself?—The tank is 7 feet to 7 feet 9 inches in depth, taking it along the middle line; it is ten feet inside the grit chambers, and 7 feet 3 inches at the outlet end; at the sides it is 7 feet 6 inches and 7 feet. The length over all, including the grit chambers, is 64 feet 10 inches, and the width of the tank 18 feet.

1871. And a description with dimensions of the filters?—Yes, my Lord. I should like to mention that the tank is arched over, as shown upon the section at the end of the plan, and in it there are 3 manhole openings, one over each grit chamber, and one at the extreme end of the tank. There are also provided plug holes, three-inch iron pipes let into the concrete, along the ridge of the tank, and one at each side, for the purpose of taking the depth of the deposit in the tank. There was also an attempt to show by an inspection chamber in the body of the tank what occurs inside; an inspection well with windows was provided, but further than seeing the increase of the deposit at the bottom and the thickness of the scum at the top, we learned very little from it.

1872. Would you give us a description of the filters, with their dimensions?—There are five filters provided, each having an area of 80 square yards, with a depth of 5 feet. One of these filters is always at rest. On the bottom of the filters are laid a series of field drains, which convey the filtrate into discharging wells: over and around the field drains is 6 inches of gravel. The whole of the works I may say are built in concrete, and the tank arch also of concrete.

1873. And what filtrants do you employ?—In Nos. 1, 2, 4 and 5 we have got a depth of 4 feet 6 inches of furnace

clinker and in No. 3, the middle one, coke, broken to pass through a half-inch ring and smaller. Several experiments were made to find out which was the best filtrant, determinations being made by estimating the nitrates in the filtrate, and the best results were obtained from the furnace clinker. It was proposed to break this so as to pass through a half-inch screen but not pass through an eighth of an inch, getting the dust out of the filtrant, but owing to hurry to get the works finished a good deal of the filtrant was larger than these dimensions.

1874. Then what is your method of distributing the tank effluent to the filters?—That was another object I had in view when I designed these works, so to make them independent of manual attention, works which could be left day and night to work continuously without any attention. In the first little tank with filters I provided an alternating arrangement. I should explain that the filtration is not by allowing the liquid to flow on to the filter, and then through away, but the outlet valve from the filter is shut down. The effluent flows on the surface, trickling down to the bottom, filling up till the filter is completely full, and then discharged. In the small installation when the filter filled a small quantity of the filtrate overflowed filled a bucket, depressing it, thereby opening the valve of that same filter and discharging it, and shutting the valve of the adjoining filter and diverting the sewage to the adjoining filter. In the present works four filters are worked all together, and the arrangement is for four filters. The same thing occurs, but it is a little more complicated. If we assume No. 4 filter to be filled it will discharge No. 2 filter, which has been standing full, and divert the sewage to No. 1. When No. 1 filter is full it will divert the sewage to No. 3, and it will discharge No. 4, When No. 3 is full it will discharge No. 1 and divert the sewage to No. 2, and so on. Each of these filters gets a rest during its work every day, according to the flow of sewage, and in that connection I should like to explain that I have made no arrangement for giving a regular flow to these filters. The filters have to take the sewage according to the curve of flow, and not in the same way as the first experimental tank was supplied. That was a uniform flow; in this case the flow is variable and the filters have to do the work as it comes along, but considering what occurs it is best to assume a uniform quantity over the twenty-four hours. These filters are rested in the following order:—Nos. 1 and 5 get three days rest in eighteen days, and the middle three get four days rest each in eighteen days. If the flow of sewage is such as to fill the filters six times in the twenty-four hours two of the filters will get a rest of eight hours each, and two of them a rest of four hours each, and so on according to the number of the times of filling.

1875. As the filters only empty after they are completely filled, I take it that it is impossible for the sewage effluent to wear any channels through them. The filters only empty after they are completely filled?—That is so, my lord.

1876. Therefore the sewage effluent cannot wear any channels for itself, can it?—The necessity for filtering in this way is occasioned altogether by the difficulty of distributing the effluent to the surface of the filter equally. It is apt to go down in pockets alongside the channels, and the necessity for filling them up is to bring the effluent as intimately as possible into contact with the filtrant.

1877. What are your automatic appliances for supplying the filters with the effluent and for discharging the filtrate?—That consists of two buckets attached rigidly to a shaft, and to that shaft is also attached the outlet valves from any two of the filters, and the inlet-valves also to the filters. There are two sets provided in this case, or a bucket for each filter. As one filter fills it will overflow to one of the adjoining pair. It will depress the bucket, it will open the valve of the filter to be discharged, and it will shut the valve of the filter to be filled.

1878. Then have you anything more you would like to tell us as to the work of the filters?—There are three difficulties in connection with working in this way that I should like to point out. In the first place, during the night the flow being small the filter takes a long time to fill, and a long time standing full, a condition which does not help matters, a condition which is not favourable to good working. The next point that has been objected to I rather think is an advantage myself, but it has been objected to that the filter being discharged with a rush is also a drawback, but I think many of the products that would otherwise stay in the filters are carried away by that rush, and air is more uniformly drawn into the filters by it. There is another point, and the most serious of all; it is, when one filter has been stopped, which has been working for some time. I have not provided a valve that can be operated from the top, a man has to get down into one of these wells and open the valve, and then make his escape before the water is on him, and as a consequence when the filter is stopped-off a large volume of water remains in it, and that I consider a distinctly unfavourable condition for the working of the filter. But I may point out that neither of these objections are inherent; that is, that they all can be got over by suitable arrangements; but even with these conditions of all the analyses that were taken of the filtrate from these works, none of them were found to be distinctly unfavourable.

1879. Would you next tell us anything about the nature and depth of the deposit in the tank, first of all after working for thirteen months, and then after working for twenty-six months?—After thirteen months working, that is, on the 31st August, 1897, the depth of the deposit found in the tank averaged 19½ inches. I have got the depths here at the different openings. The quantity then found in the tank was 66½ cubic yards of deposit, which was of the composition given by the analyses then made, as follows:—Mosture, 88·14 per cent.; mineral matter, 7·90 per cent.; loss on ignition, 3·95 per cent. Had precipitants been used we should expect 556½ cubic yards of deposit.

1880. You are taking a cubic yard?—Yes, I am taking a cubic yard for every thousand persons supplying the sewage, and there would have been 556½ cubic yards of deposit in the tank instead of the 66½ found there. Further measurements were taken on the 19th November, showing an increase. I regretted very much to have been unable to show you when you were at Exeter a section of the deposit from the bottom of the tank. I was prevented from doing so by the manufacturers failing to supply me with the glass tubes that I wanted for the purpose. Since then I got these tubes, and the next best thing I could do was to have the result photographed, so as to be able to show them to you. (*Photographs produced.*) The tube shown in the photograph is of glass a little over an inch in diameter, with a valve at the bottom, which can be shut and made tight. The tube was passed slowly down through the deposit until it rested at the bottom and allowed a certain time to rest. Then the valve was closed, the tube drawn up, and the photograph taken of it as it stood. Upon the photograph that you have there, that band across it represents two feet in height, but I observed that while the depth of water in the tank was 7 feet 3 inches, in the tube it did not come up to 7 feet 3 inches. I assume that the deposit was so tenacious that it prevented the water getting into the tube, and from being pushed up so as to give the full measure of the depth of the tank, the difference between the depth shown in the tube and the depth of the tank I have added as deposit. That one in your hand now, estimated in that way, shows 33½ inches of deposit in the tank.

1881. That is for 26 months' working?—For 26 months' working.

1882. Then in the first 13 months the deposit averaged 19½ inches, and in double that time it had only increased to 33½, is that so?—Yes, that is so. I took also photographs of other sections from different parts of the tank, which show different results.

1883. (*Professor Ramsay.*) Has this second deposit been analysed?—Yes, I have had it analysed.

1884. (*Professor Foster.*) What was the diameter of the tube?—A little over an inch—1 1-16 inches. May I pass this analysis to Professor Ramsay; I have just had it handed to me. (*Analysis put in.*) I should like to explain that this deposit as shown by these tubes—and I have never had an opportunity of seeing it under similar conditions, accounts for what happens in the grit chambers. In the grit chambers I have always found the depths to vary from day to day, sometimes more, sometimes less. This tube has shown me that there is none of that black deposit that I think I was able to show you when you were at the works—there is none of it at all in the deposit found in the grit chambers; it appears to be nothing but undigested sewage matter, whereas in the body of the tank that intensely black deposit is found, but it becomes more intensely black as we get away from the inlet and at the extreme end of the tank. I take it that the amount of organic matter—perhaps those analyses will correct me—in the deposit is less at the extreme end than would be found if a sample were taken at the entrance to the tank. I also found that the scum on the surface over the grit chambers is very much thicker than it is at the

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extreme end, where it thins down very much, and where there are open spaces of water without any scum on the surface at all.

1885. (*Chairman.*) Can you tell us anything about the gases that are evolved in the tank?—Yes, my lord. Dr. Rideal made analyses of the gas from the tanks in 1896. One sample was aspirated at the gauge well and the other was aspirated in the man-hole in the body of the tank. No. 1 is the one that is abstracted from the gauge well, and No. 2 is what was abstracted from the body of the tank. He found the percentage by volume to be carbonic acid ·3 per cent. in the first case, and ·6 per cent. in the second; organic matter to be 20·3 and 24·4, hydrogen 18·2 and 36·4. The gas found in the tank burns freely, and it has been estimated by Mr. Dibdin that it has half the value of coal gas of 16 candle-power.

1886. (*Colonel Harding.*) Of half, did you say?—Half. I have made several efforts to estimate the quantity that is evolved from the surface of the tank, and I thought I had got figures that I could submit to you to-day—the figures appeared to me to be too large. The last thing on Saturday I went down and examined the apparatus that was used, and I found that there must be an error in the observation. The mode of measuring is by cylinder and cone, which are joined by two pipes, one of the pipes from the cone to the top of the cylinder and the other to the bottom, each pipe controlled by a tap. The cone is immersed under the scum of the tank, enclosing an area of 1¾ square feet, and the cylinder being filled with water and the two taps open, the gas is aspirated; but I found from the position of the cylinder so high above the water, that there is immediately a vacuum formed, and the vacuum has not been allowed for in the figures that I had ready for you, so that I am unable to give you to-day the quantities. The correction—I should imagine from the observations I was able to make on Saturday—amounts to at least taking 25 per cent. from the figures I got, but I shall hope before long to get a series of corrections, and if you will allow me I shall submit them to your secretary.

1887. (*Chairman.*) Oh, yes, certainly. Then can you tell us anything about the condition of the filters after this twenty-six months of work?—Yes, my lord. There has formed on the surface of the filter, and more noticeably recently, a black deposit—in wet weather it forms a black slime on the surface of the filters; in dry weather that slime dries quite rapidly and breaks up. There is also undoubtedly in the pores of the filter, near the top especially, an accumulation of the same sort. In 1896, when the filters were first set to work, the quantity of water they were able to take in in addition to the filtrant was 8,962 gallons, or ·39 of the contents of the whole filter. The tests made the other day (last week) showed a quantity equal to 6,349, or ·28 of the contents of the filter. I rested one of the filters, No. 2, and I discharged the water in it, and then measured the flow to it, when I found it to be 7,170 gallons, or ·32 of the contents of the filter. The same thing is shown by the number of fillings. A journal has been kept from the beginning of the working of the plant, and during 1897 the number of filter fillings, the average number was 6·81 per day, while the average number in 1898 for the same period was 8·18, showing that there is a reduction in the quantity of water that the filters can take in of about 25 per cent. in about two years. Otherwise, the working of the filters seems to be the same now as shortly after they were set to work.

1888. Then as to questions of cost, what would you say as to the cost of the installation of works for disposing of sewage by this method?—I have got only a few figures to submit to you, and shall take first the present installation at Exeter, and I have taken the quantity as that for which they were designed, namely 81,000, but I have also given the figures for the average quantity dealt with, which was 54,000, but taking it at 81,000, the cost came to 8s. 7½d. per head of the population, and £8 per thousand gallons treated a day.

1889. (*Colonel Harding.*) Were you about to give us those for the reduced quantity?—I have not worked them out, but it becomes higher, of course. There is a caretaker who was at the construction of these works, and he was retained to look after them, and this year I have taken the total cost of the man's time on these works, and I have included every other work he did as well as what was required for the special attention to the filters. All that is required really is to go down once every three days or once every two days, and change the resting filter; but there is a lot of other work done, the cultivation round the works, and so on; that is all included in the figure I am about to give you. That came to £25 2s. in the year, or ·3 of a penny per thousand gallons treated. I should like to explain further, my lord, if you will allow me, that for the large installation at Exeter the estimated population for which provision is made is 47,000, and the maximum dry weather flow to be dealt with is two and a-half million gallons a day, and the estimated cost of the works—and I may say that I have kept my figures high—is at the rate of £6 17s. per thousand gallons treated per day. I can only estimate the maintenance cost, and allow the same that I estimated at the time in reporting to the Council, that was the wages of three men at a pound a week, and that works out at ·05 of a penny per thousand gallons treated per day.

1890. (*Chairman.*) What is included in the cost of the installation. It is the building of the tank and the filters, but does it include any of the drains to sewers?—It does not include the intercepting sewer to the tank, and it does not include the outfall sewer from the works. It only includes the works, the grit chambers, the buildings, and the penstocks and valves required for regulating the flow. An installation has just been completed for the town of Barrhead. It has been designed for a population of 10,000, and the maximum quantity to be dealt with is 400,000 gallons per day. That works out at £11 17s. 2d. per thousand gallons treated, and I have contracted, or rather my friends have contracted, to take charge of these works for three years at the cost of the wages of a man at 30s. a week. That works out at ·13 of a penny per thousand gallons treated per day. A tender was obtained for Wallingford. They were anxious to know how our estimate would agree with the tender, and I am glad to say that they were within £8 of each other. The tender received gives the cost of the works. This is for a population of 2,989—of 3,000 population—dealing with 90,000 gallons per day. That gives £18 13s. 8d. per thousand gallons treated per day. The smaller the installation the cost will be greater than for a larger. Warley, in Essex, was for a population of 500; 20,000 gallons was the maximum quantity to be dealt with, and the cost there is £23 17s. per thousand gallons treated, the maintenance cost being ·33 of a penny per day. St. Budeaux, a population of 500, dealing with 15,000 gallons per 24 hours, the cost comes to £22 15s. 4d. per thousand gallons, and the maintenance cost ·40 of a penny per thousand gallons. These are all that I am able to give you, but the only one of them being an estimate is Exeter, and also being the largest. All the rest are small in comparison, but it must be evident that no comparison can be drawn of the cost of works from information of this description. There are so many causes at work to vary it—the quality of the sewage to be dealt with, local conditions and the facilities for constructing the works, the size of the installation especially. In our case the caretaker could attend to works ten times the size, and the cost of maintenance would be obviously so much less.

1891. Now one of your main principles is, I believe, the complete or the almost complete liquefaction of all solids in the sewage by fermentation set up by the action of anaërobic bacteria, is it not?—This last year's estimation showed that 80 per cent. of the suspended solids were got rid of in that way.

1892. Do you believe that without your closed tanks this anaërobic bacteria would either not come into existence, or would cease to exist too soon?—I am not qualified to speak upon this question; I am not a bacteriologist, and I can only give my own uninformed opinion upon the matter.

1893. Oh, yes, quite so?—But I found a paper was read by Dr. Adeney, of Dublin, before the Congress of the Sanitary Institute at Birmingham last month, and he defines in it what anaërobic fermentation is. His definition is:—"We may take it, from what has already been said, that a river becomes over-polluted when the bacterial fermentation in its waters becomes so rapid that the atmospheric oxygen dissolved in them is consumed by the bacteria more quickly than it can be replenished in the ordinary way, that is, by ordinary solution and diffusion through the water of fresh quantities of oxygen from the atmosphere. When this state of things arises anaërobic fermentation sets in, attended with all the offence and dangers of putrification." With regard to sewage, if this definition is correct, and I have no reason to doubt it is—because I think Dr. Adeney has contributed more to this subject than any other who has

taken it up—if this definition is correct, then anaërobic conditions exist in the sewage from the outset. Dr. Dupré has shown that thirty times the volume of river water will render sewage innocuous, it would be necessary then to supply that quantity of water under the conditions stated by Dr. Adeney to prevent or to put a stop to putrefaction, or a supply of oxygen must be given artificially. Again, the experiments made and carried out by the Massachusetts Board of Health show that the organisms isolated from the sewage, with very few exceptions, thrive in the presence or in the absence of air equally well. Whether the organisms coming in with the sewage into this tank get their supply of oxygen from the surrounding organic matter, they certainly, I do not think, get it from the atmosphere, but whether they are aërobic organisms that are able to work under the conditions in the tank I am not able to say.

1894. You are not able to say whether they are altogether aërobic or anaërobic?—No, or whether they are able to exist under these conditions. The only thing that I have been able to notice has been that after putrefaction had become evident, the number of micrococci declined and became very few, and again after putrefaction was over the numbers seemed to increase. These are from my own crude observations on the subject. But one thing I should like to say—I daresay it will be put before you better than I can possibly do it—but my difficulty has always been to realise how a visible particle of suspended matter in the sewage compares with the size of the organisms, how the one can be seen by the eye, but the other requires a twelfth eye-piece to be able to see it, and that, therefore, if anaërobic conditions are not to be allowed, I do not see how this sewage can be broken down.

1895. Practically what length of time do you think ought to be allowed for the fermentation process by which the solids are liquefied?—The time of stay of sewage in the tank varies with the flow, and ordinarily if the flow is 53,800 gallons per day, the stay of the sewage in the tank from the time it enters to the time it leaves it again is 24 hours. I found 18 to 20 hours stay in the tank as the best condition for filtration, but another set of conditions is set up altogether when we come to notice what happens. It has been shown that with a velocity of three feet per second deposit takes place. In this case the velocity at maximum flow is not more than 1¼in. per minute, instead of three feet per second, and what happens is that a deposit takes place both at the bottom and at the top of the water. The scum is formed at the top and the deposit at the bottom, and that gets a very much longer period to be worked upon than the sewage containing the matters in suspension that also undergoes a certain change in its passage through the tank.

1896. The time would vary, I suppose, with the strength of the sewage and the warmth of the weather?—Undoubtedly. I think the action is much more rapid when the sewage is fairly concentrated and when the weather is warm.

1897. You have had the sediment at the bottom of the tank analysed now for the first time, is that so?—No, an analysis was made by Dr. Rideal.

1898. This is the first time that you have had that done, is it?—No, my lord, it was done in September, 1897, as well. What I have read out to you was done in September, 1897.

1899. Did you give us the analysis that was made in 1897?—Yes: I gave you the mineral matter, the organic matter, and the water estimation.

1900. Can you tell whether any further fermentative or putrefactive action takes place in the sediment after it has once settled on the bottom of the tank?—In the sediment, yes, my lord, and that continues for a considerable time. Comparing the deposit taken from the old tank, which has been resting now since the new works were started, I find on warming the two deposits that from the present tank swells considerably, whereas the other remains inert, so that there is undoubtedly a lot of organic matter still remaining in the sediment. What it is I think Dr. Rideal has given.

1901. (*Professor Ramsay.*) About three per cent., I think?—Yes.

1902. (*Chairman.*) Of the total solids that go into your tank can you give us any estimate of the quantity that remains there as sludge or sediment, and which you will have some day or other to remove?—In 1897 we should have to remove 66½ cubic yards of matter. We shall have less than double that quantity in two years, and at present I am working the tank so long as it will work, to see the period required to have to clean it out, but I have suggested a provision that may render it unnecessary almost to completely empty the tank at all. I propose to have a channel carried down at the outlet having a slotted pipe leading out, so that a quantity may be taken away periodically—in small quantities, and I almost think that that will put off for years the necessity for removing the sediment entirely from the tank.

1903. Out of a hundred per cent. of solids that go into the tank can you form any opinion at all of what quantity is liquefied in the tank?—80 per cent. appears to be liquefied.

1904. Eighty per cent.?—About 80 per cent.

1905. Then, in fact, you get rid of 80 per cent. of your solids altogether?—That is so.

1906. You have had the effluent of course analysed both chemically and bacterially?—Yes.

1907. And you can let us have the analyses that were made?—Yes.

1908. (*Professor Ramsay.*) Might I ask at the same time that Dr. Rideal's analysis may be put in?—This one?

1909. Yes?—Yes.

"Chemical Laboratory,
28, Victoria Street, Westminster,
London, S.W.
October 17*th*, 1898.

To Donald Cameron, Esq.,
City Surveyor, Exeter.

Examination of Tank Effluent,
October 14*th*, 1898.

Amount of Suspended Matter—12·90 parts per 100,000.

Composition of Suspended Matter:

Mineral Matter	32·25
Organic Matter	67·75
	100·00

The nitrogen amounted to 3·18 per cent. of the dry sediment. The real or equal to 4·70 per cent. of the organic matter.

The relative amount of soluble and insoluble organic matter in the tank effluent is shown as follows:—

Parts per 100,000.

	Unfiltered.	Filtered.	Suspended.
Organic Nitrogen ...	1·235 ...	0·824 ...	0·411
Oxygen consumed ...	3·12 ...	1·40 ...	1·72

Examination of the deposit in tank at different depths.

Percentage composition of deposit dried at 100°C.

	3″ from bottom.	9″ from bottom.	15″ from bottom.
Mineral Matter ...	67·65 ...	67·60 ...	68·69
Organic Matter ...	32·35 ...	32·40 ...	31·31
Nitrogen	2·38 ...	2·34 ...	2·45
Nitrogen in Organic Matter.	7·36 ...	7·22 ...	7·82

The sediment of the tank effluent contains more organic matter than the deposits in the tank, which it is seen do not differ materially at different depths.

The organic matter in the tank effluent is more carbonaceous and less nitrogenous than that which remains at the bottom of the tank.

From a microscopic examination of the above three deposits I find that they consist of a black amorphous matter, with vegetable and animal debris much altered, and cominuted. No marked difference in the severa depths was noticed except that in the lowest deposit there were great numbers of large amœbæ whilst in the upper one anguillulæ were prevalent, which may indicate somewhat different action in the different layers.

SAMUEL RIDEAL."

I intended to describe what comes away from the tank as effluent, and what comes away from the filters as filtrate. Such a terminology is necessary.

1910. (*Chairman.*) You have had both the effluent and the filtrate analysed both chemically and bacteriologically?—Yes, we had the sewage, the corresponding tank effluent and the filtrate analysed, and that was continued over a series of many days; samples were taken every hour. samples bearing a proportion to the flow at the time at which they were taken.

1911. And then these analyses you can let us have?—Yes. I understood, my lord, from the Town Clerk that

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your secretary had been supplied with copies of the reports of the chemists that were before the inquiry of the Local Government Board.

1912. I suppose that you have not had the effluent from the septic tank examined for enteritides or the reduction of coli?—No, my lord, I do not remember that Dr. Sims Woodhead speaks about it in his report, but if so it is in that report of his included in that book.

1913. Do you consider your filters or your filtrate would be affected by frost?—During 1897, when we had a fortnight's frost—January 27th, 1897—after the frost had been on for a fortnight, the filtrates were so beautifuly clear that I sent three samples to Dr. Dupré to be analysed, and this is his report upon them:—"The three filtered effluents are all extremely good, the best being No. 2, the next best No. 3, and the least good No. 1. They are all almost inodorous at ordinary temperature, but No. 1 and No. 3 have a slight musty smell, like river water, when heated to 100° F. No. 2 remains almost inodorous, even at that temperature. All three, though slightly opalescent when received, gave no appreciable amount of deposit on standing for twenty-four hours, and remained free from deposit after a week's keeping in my laboratory. They, indeed, became more clear, without depositing any amount of sediment. They are all three fully equal to average effluents from well-managed sewage farms, while No. 2 is equal to the best of such effluents. They are superior to any of the former effluents received. In my opinion, these effluents might, with perfect safety, be allowed to run into a very small brook or even into a ditch in which they formed the main or sole current."

1914. Then you do not think a hard frost would put your filters out of order at all?—We have not had that experience, my lord, but as far as I can see the working of the filters is independent of the temperature.

1915. Have you got any idea as to this question: If the sewage is largely diluted with rain or other pure water, would your system work better or worse than if it were sewage only diluted to a very small extent with rain or surface water?—Yes, my lord. Then the work would fall principally upon the filters, and if the filters are proportionate to the quantity of sewage the work would go on equally as well.

1916. And do you think that either the sediment that is left in the tank or the filtrate that issues from the filters could be used for manuring purposes?—Undoubtedly it could, both of them could.

1917. Both would be valuable?—Both would in my opinion be valuable, but I have made inquiries this year of the surrounding farmers, the farmers surrounding the works at Exeter. We have had, as you know, my lord, a very dry summer—a considerable drought in Devonshire—and they all agree that it would add £1 an acre to the value of the land that could be irrigated with the effluent.

1918. (*Sir Richard Thorne.*) The tank effluent?—The filtrate, taking it even as pure water.

1919. (*Major-General Carey.*) Being an exceptional season?—Being an exceptional season. The value of it would depend upon the season, undoubtedly.

1920. (*Professor Foster.*) That is, it will have no distinctly manurial value. You are regarding it simply as so much water, not as a solution of nitrates?—They were so regarding it, but I am regarding it as having a greater value than that.

1921. Your answer refers to what the farmers said?—To what the farmers said.

1922. And that was simply as pure water?—As pure water, yes.

1923. But you yourself are of opinion that simply for the nitrates it would be valuable?—Quite so; I consider it a waste, and a pity that it should be wasted. And that value, of course, will vary according to the sewage. In the sewage of Exeter, I think, ·83 or odd is the nitrates in parts of 100,000. In the sewage of Yeovil that figure only runs up to 10 parts. Such a filtrate would be much more valuable and would enable a greater outlay to be made to convey it to the land than the weaker domestic sewage.

1924. (*Chairman.*) Could you either tell us now, or if you prefer it, send us a short statement in writing, showing where your system is at work besides Exeter, and besides sewage, what trade refuse it deals with?—Very well.

1925. Perhaps you could send it to us in writing, because we propose to make as thorough examinations as we can of the various systems now in use. We also wish to ask you if you would allow persons appointed by us to have access to your works in different places for the purpose of examining them, and if you would also allow these people to take samples at their discretion?—Certainly, my lord. I think I have asked General Carey if he would send down a responsible officer to take charge of these works at Exeter and do what he pleases with them.

1926. I do not think the Commission want to have the responsibility of the works, the charge of the works. The people appointed by us may go to the works and look over them and take samples at any moment that they think fit?—I should have liked that the officer appointed by the Commission should have had charge of the works, so that they might have been worked under whatever conditions he wished.

1927. Could you give us any description corresponding to the anaërobic treatment in the tank of the aërobic treatment in the filter?—No, my lord, further than so long as the effluent is in such a condition that it could be filtered without mechanically clogging the filters, I do not follow the subject, and the question of nitrification is one of which I have no knowledge practically. As regards the filters I adopted Mr. Dibdin's method. The only thing I can say in addition is this, that besides the chemical action that goes on in the filter there is also an undoubted straining action, and that the filters hold on their surfaces the fine matters that come out of the tank.

1928. Have you anything you wish to add to that?—I should like to add, of course, that in adopting Mr. Dibdin's method of filtration I made the action of the filters automatic.

1929. (*Sir Richard Thorne.*) Do you mean the material of which the filter is composed retains on its surface particles that come from the tank, or are you speaking of the surface of the filter generally?—The immediate surface of the filter, and for a certain distance down, but the greatest quantity is on the immediate surface. I should have mentioned that there may have been an error in observation in taking the quantities that the filters could hold. I noticed that when a filter was full and had diverted the sewage to the adjoining filter, it will afterwards go on filling as if the upper layers of the filter offered sufficeint resistance to the effluent to cause the gear to divert the sewage to the adjoining one, but afterwards they gradually sank, and a further quantity came in, so practically, I think, the figures that I have given you are correct.

1930. (*Mr. Killick.*) You gave us several analyses of the raw sewage on the four hours' test—I think they run, 3·158, 4·66, 2·028, 4·30. These show a very wide range of differences. Can you explain this?—I can explain one of them, that is Messrs. Pearman and Meor.

1931. Which is that?—The last one. Instead of taking samples over the twenty-four hours, they analysed samples taken at one o'clock in the afternoon; but for Dr. Dupré's I cannot account.

1932. That is the low one?—No, that is the high one.

1933. No, but there is the high one, 2·028?—The low one. That was taken over the twenty-four hours, during a considerable flow of sewage, indicating plenty of water, a lot of dilution.

1934. These were not all taken on the same day?—Not on the same day, no; these are the results of different observers.

1935. (*Professor Ramsay.*) I wish to ask whether Mr. Cameron has noticed whether putrefaction goes on equally well in the septic tank when the sewage is exceedingly dilute?—I have got the impression that the action is not so rapid when the sewage is diluted.

1936. But have you any positive experiments to show?—The only experiment that I can give is the production of gas. The gas burns less freely during wet weather than it does when the weather is dry.

1937. Then another point I wish to ask about is the anaërobic fermentation in the open tanks. I want to know if he has noticed whether anaërobic fermentation will go on in tanks?—I think it will. My first idea was to use only an open tank and not a covered tank, and so long as the scum is formed on the surface I think anaërobic fermentation is going on.

1938. Does anaërobic fermentation cease when the scum is destroyed?—I do not think it does; the production of gas does not cease.

1939. Were your original tanks covered?—All of them.

1940. From the very first?—From the very first, yes.

1941. (*Mr. Killick.*) With regard to what I asked about the analyses of these samples of your raw sewage, they are merely tests of the sewage on different days, and therefore of very little value for comparison one with the other?—The sampling and the analyses were carried on a constant 24 hours' analyses during a fortnight's duration.

1942. But you have told us that was not the case in one?—Mr. Dibdin's is the average of that fortnight's.

1943. Was it the same fortnight for each of these four analyses, during the same fortnight?—For Dr. Rideal's and for Dr. Dupré's. I have not been able to give you a figure of Dr. Dupré's, but Dr. Dupré's and Dr. Rideal's were for a fortnight.

1944. The same fortnight?—No; not the same fortnight.

1945. There is no comparison; sewage might vary from day to day, from hour to hour?—From hour to hour.

1946. (*Colonel Harding.*) As to the grit chambers; you told us that you had a grit chamber placed some distance in advance of your works at Exeter?—Yes.

1947. And that you had found a certain deposit of other matters there besides mineral matters, but you got rid of them by stirring up, and so getting them washed away?—Washed into the tank.

1948. Has any system occurred to you at all by which the grit could be precipitated alone without intercepting the organic matter which so rapidly deposits upon it?—The only suggestion is to revert to the original conditions of the tank, and with the grit chambers at the entrance of the tank receive all that the sewers bring along.

1949. Then in that case would you not have in the grit chamber an accumulation of other matters besides those you wanted to precipitate?—Undoubtedly, but a very active washing action goes on in that chamber; immediately a sample is taken from the bottom in a glass tube the gases stream from the bottom, showing a very violent action in the whole of the tube.

1950. A violent action in the grit chamber?—In the grit chamber.

1951. And do you think that that action is to bring to the surface and so get carried forward the organic particles?—That is my opinion.

1952. You did tell us as to the amount of deposit in the septic tank, but I did not gather that you told us to what extent matter had deposited in the grit chamber, nor how far it had been removed from time to time?—In the grit chamber none has been removed; nothing at all has been taken out of the grit chamber, and the depth in the west grit chamber on the 31st August was 14 inches. That is after more than one year's working. The depth in the east one was 24 inches. At the time of Dr. Thomson's and General Crozier's examination, the depth was 15 and 27. Some days later the depth varied again. If I was not aware that there was nothing taken out of these grit chambers it would be hard to make me believe that there had not. From the variation that takes place in these grit chambers, if I was not aware that nothing had been taken out of them I would be under the impression that there had been.

1953. (*Professor Foster.*) But are your grit chambers not cleared out at intervals?—They have not been cleared out yet. The little grit chamber higher up has been cleared out.

1954. (*Colonel Harding.*) Is not the inference that there must be some other settlement of grit besides the two that you are talking about?—Undoubtedly. I have observed earlier in the day that the brick gully pits, large brick chambers, are very much more efficient in keeping back detrital matter than I ever thought they could be; in fact, what reaches the little grit chamber in the lane is principally the earthy matter, the earthy matter on the road surfaces and the portions that sometimes get washed into the manhole cover.

1955. Then the probability is that under other circumstances a much larger grit chamber would be required, and that the grit chamber would have to be pretty frequently emptied?—My intention was, sir, to reduce the size of the grit chamber, from the experience that we have had here. If the gully gratings were not so efficient in removing the detrital matter, undoubtedly it would have to be removed from the grit chambers.

1956. In any case we may take it you do not desire that the grit should go into your septic tank?—No, although there is a lot of fine sandy matter still carried forward into the body of the tank.

1957. Now, as to the accumulations of sludge in the tank itself. I gather that you told us there had been, after thirteen months' working, 19½ inches accumulation, and after twenty-six months working, 33 inches accumulation. Did I understand you to say that you estimated that to represent 66½ cubic yards?—The first 19½ inches represents 66½ cubic yards.

1958. As the accumulation in the second year was about equivalent to the first year it would be about an accumulation of 66 cubic yards per annum?—An accumulation of 66 cubic yards per annum, but before giving the figures or relying upon them very strongly, although the means adopted were better than we have had yet, still I would like to try over the whole surface of the tank as far as I can get at it.

1959. You anticipate, therefore, that it will be necessary from time to time to remove this sludge, this accumulation of sludge?—At first I gave particular attention to the accumulation of the sludge, and for the first two months it increased at the rate of one inch per month. Then I considered that we should have at some period or other to clean out the body of the tank.

1960. You told us that the stay in the tank should be 18 to 20 hours to obtain the best results from the filters?—That is the period which I found to give the best results.

1961. And what speed per minute does that give you of the flow?—In the case of the present tank it gives us about one inch per minute.

1962. And up to what speed per minute do you think you could go without interfering with the efficiency of that tank?—I propose that in the new works it should go up to the speed of five inches per minute, but I think we could go very much higher than that without at all interfering with the action of the tank. When Dr. Dupré was asked that question he said "He was afraid," without calculating the speed at which the sewage passed through the tank, "it would wash the living machine out of the tank." But I afterwards pointed out that such a speed, that is, five inches per minute, could not possibly wash the deposit from the bottom nor the scum from the top, consequently the living machine still remained in the tank.

1963. You have told us about the production of gas in the tank, and we saw when we visited Exeter that to some extent you utilised that for lighting purposes, and some suggestion was made that it might be utilised for heating purposes. Would not that involve the construction of those tanks in some non-permeable material, such as iron?—What I proposed to do with the new works was to cover the concrete with bitumen, bituminous substance that would prevent the leakage of the gas. At present there is undoubtedly no pressure in the tank. That has been abundantly tested by Mr. Dibdin. That being the case, the gas must escape as freely through the concrete surface of the tank and the soil, as it escapes at the mouth of an open pipe, and to prevent that leakage I propose to cover the surface of the tanks with pitch.

1964. Now, comparing the work of the tank with the filter, you would claim, I suppose, that the work of the tank was mainly to get rid of the matters in suspension. You do not claim that the tank will do much more, do you?—There is undoubtedly a change in the tank; the organic matter is undoubtedly changed greatly into ammonia, and into gas, which of itself is a very big change.

1965. You have some figures, have you not, as to the relative purification obtained by the septic tank and the filters?—Yes.

1966. Can you just roughly give us the average?—They are all put together in a report that I had just now, but they are given in these several reports that are before you.

1967. Give us any one instance?—I will take Dr. Dupré's. Percentage of purification effected in the septic tank, as measured by the oxygen absorbed 63·5 per cent.; as measured by the reduction of organic nitrogen, 27·7; the work done by the tanks and filters combined brings the purification on the oxygen absorbed up to 88·3 per cent., and on the organic nitrogen to 84·9.

1968. Then the main advantage you claim for the use of the septic tank is the destruction of the solid matter, and getting rid of the sludge difficulty?—There is, besides that, another advantage, that it smoothes or equalises inequalities in the sewage. An example may be given of the chlorine. At night the chlorine is found to be a little over 2.

1969. (*Professor Foster.*) In the sewage?—In the sewage. At time of maximum flow it is found to be over 10 parts per 100,000. The tank effluent invariably gives the mean, or nearly the mean, of those figures, so that the tank has smoothed the night flow, or mixed the night flow along with the day flow. And it has this advantage that if a dose of chemicals should be sent into the tank, that it is diffused throughout the whole sewage in its stay in the tank.

1970. (*Colonel Harding.*) Now as to the filters. You gave us your experience in regard to material, that furnace clinkers had proved to be most effective?—Yes.

1971. You do not think that the porosity of coke, then,

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is of much value. I take it that the clinkers would be largely vitrified, would they not?—Yes; I rather look upon the porosity of the coke as a disadvantage. Filter No. 3 is the one which is filled with coke, and I know that the filtrant in it is broken coarser than the clinker of the adjoining filters. Aeration is the secret of filtration, as far as I can understand it, and the quickness with which a filtrant gets rid of or drops the water that has been sent on to it the better the aeration should be, but although the filtrant in No. 3 is coarser than the filtrant in No. 2 and No. 4 it takes a longer time to part with the drainings or the residue of the effluent left in the filter, and I attribute that to the porosity.

1972. The effluent from the tank contains in suspension very finely divided particles which you yourself speak of as humus?—Yes.

1973. Do I understand that you think that is matter which will necessarily accumulate in the filters—matter, that is, that cannot be liquefied by aërobic bacterial action?—I think the particles of organic matter attached to these particles will be dealt with on the filters. The accumulation of these fine particles on the surface of the filter has necessitated in two years the removal, on an average, of two inches over the surface of the filters. I say an average, because the greater part of the deposit took place in the immediate vicinity of the channels where it had to be taken a little deeper, but the average quantity which has had to be removed in two years has been two inches. I believe a fine layer, a finer layer than I put there, will render the removal of such a quantity unnecessary, even for the same period.

1974. The removal, I suppose, was necessary, because it stopped the passage downward of the effluent from the tank?—It stopped the passage downward, or the rate of the passage downward, into the filter.

1975. At Exeter you are dealing, as we saw, simply with domestic sewage. You have not said anything to us to-day about the one case where, I believe, you have so far had experience of trade effluents, namely at Yeovil?—No.

1976. Can you tell us anything about results at Yeovil as compared with the results at Exeter, and can you tell us as to the difference in the sewages themselves of those places?—The works at Yeovil were put up to deal with a sewage which is reputed to be the foulest in England. The Council wished first to try if such a sewage is amenable to this treatment, and I think the results have demonstrated that it is so. The variations in Yeovil are very much greater than in Exeter, but on the other hand the percentage of purification in consequence of the foulness of the sewage shows very much higher, although the result is not so good as we get in Exeter.

1977. We have had in the papers you have put before us many examples of analyses from Exeter, but are there any analyses available for Yeovil?—No, sir.

1978. Or, can you yourself give us now something like the average results obtained at Yeovil?—I am sorry that I brought none of them with me, but I can supply them to the Secretary if you wish it. Mr. Dibdin made a report upon the sewage, and I am not sure whether Dr. Rideal did, but Mr. Naylor, the Inspector of the Ribble and Mersey Board, made an analysis for the Somerset County Council, and these I can supply.

1979. (*Major-General Carey.*) Was that since the filters have been altered or improved or before?—Before they were altered.

1980. (*Colonel Harding.*) Although the sewage at Yeovil is no doubt exceedingly foul the foulness is mostly of one character, is it not; it arises from the effluents of fellmongeries?—Yes, and brewery refuse.

1981. Is there brewery refuse?—There is one brewery upon that sewer, and in addition to that other chemicals are used in the manufacture of leather, for glove-making a large quantity of arsenic is used.

1982. It would be interesting to know to what extent there was arsenic, because the effect of arsenic would be antiseptic, would it not?—That I am unable to say.

1983. Do you happen to remember what oxygen absorbed in four hours the crude sewage of Yeovil would give roughly?—Speaking from memory I cannot give you sewage, but I can give you a tank effluent—10.

1984. The tank effluent 10?—The tank effluent 10, yes.

1985. Then do you remember what is the average of the nitrate?—I do not; I cannot speak with any certainty.

1986. Could you give us that information?—I can.

1987. (*Major-General Carey.*) There has been no analysis recently made of the Yeovil effluent?—The latest were made by Mr. Dibdin.

1988. That is some time ago?—No; about a month ago. I may say that the Yeovil authorities—their surveyor sends up the samples and takes these analyses, and I only see them if I ask for them.

1989. (*Professor Foster.*) I understand you do not profess to speak upon the bacteriology of the question?—No.

1990. I gather that that little intercepting chamber is the only chamber from which you remove things?—That is so.

1991. What you remove consists not only of grit, that is to say of inorganic particles, but of a great deal of organic matter?—I have provided the caretaker with a paddle, so that he can stir it thoroughly up before he puts in the shovel to take out the grit from the pit.

1992. So that practically a good deal of organic matter is removed at that time?—What is adhering to the sand.

1993. For instance, do you have corks in your sewage?—Well, strangely enough we have had very few corks come down to the works.

1994. But if they did come they would be intercepted in this little intercepting chamber?—In that little intercepting chamber, yes; and they would probably be intercepted in the inlet pipes to the tank.

1995. Anyhow, I suppose there is no solution of corks in your septic tank?—I am not aware of any.

1996. I am so sorry that I was not able to inspect the works myself. You speak continually of the scum which gathers on the surface of the septic tank. The effluent is taken off beneath that scum?—Yes.

1997. Is that scum increasing or does that remain constant in depth?—The scum in the winter time increases in depth.

1998. To what extent?—To between two and three inches. In the summer time the whole body of the tank is practically free from scum; it has disappeared. I take it that the warmth of the weather influences the action that decomposes it or decays it.

1999. Has that been examined, that scum as to its nature?—Yes.

2000. I do not mean merely containing so much nitrogen?—Microscopically.

2001. No, no, I mean as to the substances of which it is composed?—It has been only examined microscopically.

2002. Your sediment has not increased from your statement so much of late as it did at first?—From the measurements I was able to take last week it has not; it has not increased at the same rate.

2003. So that the increment of sediment is diminishing?—Is diminishing, but at the same time the quantity, the dust-like particles that come away with the effluent appear to be more numerous or on the increase.

2004. That is to say, the particles which ought to have been retained in the sediment, some of them come away in the effluent, is that what you mean?—That is so. There appears to be a washing action, a continual rising from the bottom and a dropping again to the bottom going on, and the particles coming in front of the slot of the outlet pipe are drawn with the discharging effluent.

2005. I understand that the gases which are given off are used for lighting purposes?—Yes.

2006. So that they give you a rough measurement of the amount of coal gas, at all events, which is being produced?—Yes, sir.

2007. I think you said that when there was a great deal of rain your illumination was diminished, that is to say, the amount of gas given off was diminished?—Yes, then I was referring to a jet that I light in the surface close down to the top of the tank. I have not observed the same thing with the lamp. Of course, the light is obtained from the gas with the aid of incandescent mantles.

2008. But by means of this jet, you have a means of roughly measuring the amount of gas which is being given off. I mean if there was any marked changes that would show them, would it, or would it not?—It appears to me to be more rapid during warm weather than during such a day as we have got to-day. But the reason why I am unable to estimate the quantity is that it is leaking away from the tank all over the surface apparently.

2009. I understand that it does not accumulate so as to give rise to any pressure at all?—That is so. Mr. Dibdin made a very careful trial. I have tried it myself with the gauge which is used for estimating the pressure on the lamps in the town, and shutting off and on quickly I could obtain no indication of any pressure. Mr. Dibdin tried a more delicate instrument, and failed to find any pressure.

2010. Has it occurred to you that an increase of the pressure of the gas might interfere with the changes which are taking place below?—No, sir. There was one accident happened when taking samples of the deposit from the tank. Taking samples one evening the gas was ignited, an explosion took place, blowing off the manhole covers. The two following days I observed the effluent from the tank was much clearer than it had been previously or afterwards, but further than that it has not occurred to me what influence pressure might have on it. I may say that I have burned it off continuously for three days at a stretch.

2011. I do not wish to speak to you much about the filters, because you say that is not so much your province, but I understood you to say that for the filters to remain full for any length of time or beyond a certain time was not good for them?—That is so.

2012. That is to say, I suppose, there is a particular length of time during which they should be full or during which the materials should stay, the fluid should stay in the filter?—Yes.

2013. If it is less than that—I mean if the fluid were run through too quickly the change would not take place, and if the fluid remains in the filter too long the change is not relatively so great?—The result is not so great; that is to say, so much is this the case that we have now devised a time arrangement for discharging the filters with the new apparatus, when a filter fills it diverts the sewage to the filter to be filled, and remains itself full until a set time, an hour, an hour and a quarter, or whatever time may be fixed for it, and then discharges itself. There is nothing to be gained by letting the filter stand full more than an hour with our sewage.

2014. Are you at all inclined to think that there are special changes taking place in your septic tank, not merely the general diffusion of several parts of the sewage as it comes in, and not simply the mere solution of the solid matters, but changes by which the material of the sewage is made, so to speak, easier to be worked upon by the organisms in the filter?—My view is that the water between the two layers, the top layer and the bottom layer, is undoubtedly acted upon in its passage through the tank.

2015-6. Quite so; beyond mere solution of visible particles, or are you speaking only of the solution?—I am speaking now of the parts in solution.

2017. Then the material in solution is acted upon?—Then the material in solution is acted upon.

2018. And that action is of such a character as to facilitate the subsequent action of the filter?—Yes, undoubtedly the ammonias are increased; an unstable condition is set up.

2019. That is the general view you have. Have you any special number of facts upon which you base it, or is it merely a general conception to which you have been led?—That is a conclusion to which I have been led by the odour that arises at the outlet pipe.

2020. By the odour?—By the odour. It is distinctly an ammoniacal odour; but the analyses that have been made will, I think, indicate the same thing.

2021. No one has examined either your sewage or your sediment in the tank with the view of ascertaining what are the accual constituents. I mean, for instance, how much cellulose there are in your sewage or what is the condition of the cellulose in your septic tank?—No, sir.

2022. Nor has any one examined zoologically with care your septic tank, have they, beyond the bacteriological examination?—No, sir.

2023. That is simply by the ordinary system?—Yes.

2024. I see Dr. Rideal speaks of various species of animal present in your sediment?—Yes.

2025. But has any zoologist actually determined them?—I do not think so.

2026. (*Major-General Carey.*) The samples that you have taken for analysis, have they always included the first flow from the filter, or has a certain interval of time been allowed to pass before the first sample was taken?—The intervals are these, sir; one minute after the opening of the valve a sample is taken; three minutes, six minutes, ten minutes, and twenty minutes. These figures were arrived at to get equal volumes of discharge, and the analyses were made from these samples mixed.

2027. From the samples mixed together?—From the samples mixed together, but analyses have been made of the first and of the last.

2028. Of the first rush?—Of the first rush.

2029. Before the first minute?—At the first minute.

2030. Before the first minute; the moment the valve was open, and it came from the filter?—Immediately the valve is opened a minute is allowed to elapse, and then the sample has been taken.

2031. Why has a minute been allowed to elapse?—That was for the purpose of dividing up the quantity that was discharged from the filters so as to get a sample from equal volumes discharged, but I may say that the filtrates so taken have been taken separately, and determined by the amount of oxygen consumed, and in many cases they gave a uniform result from the beginning to the end.

2032. What is the maximum rate of filtration of the dry weather flow at Belle Isle? I think you gave us the first experiments?—It would go on at the rate during dry weather, running up to 81,000 or 82,000 gallons.

2033. But in gallons per square yard?—That would be taking the average that we have dealt with. It would vary from 800,000 gallons per acre per day; it would vary from 170 gallons per square yard to about 200 gallons per square yard.

2034. Have you never been below that rate?—During a continuation of dry weather, I gave you the average.

2035. I mean the dry weather flow?—During the continuance of a long spell of dry weather we should be under that quantity.

2036. Do you consider that rate is a safe working rate, 170 gallons per square yard per diem?—Anything up to 1,000,000 gallons, but I have worked at the rate of over 1,800,000 gallons per acre per day.

2037. In storms?—In storms.

2038. That is what I want to come to. Is the same rate allowed at Yeovil where the sewage is mixed with trade refuse?—I cannot recollect, sir. The flow there is uniform to the tank and filters.

2039. But is it slower than 160 gallons per square yard?—That I am unable to tell you.

2040. I should like to know that?—I will find that out by to-morrow, if I can.

2041. Now, let us go back to the storm water. As I understand you, 3½ times the dry weather flow can pass through the tanks and filters; is not that so?—Yes.

2042. The dry weather flow remains a certain period in the tank, say 18 to 20 hours, which you said was the most efficient period, I think, and this period is suddenly shortened by the admission of a large volume of storm water. Is the bacterial action equally effective, or is it seriously lessened by the increased volume of water?—Several of the analyses taken were during such conditions of weather when the flow was very much swollen by rain water. If the large quantity that I mentioned, the maximum quantity for filtration that I mentioned to you, continued for a certain length of time the filters would become waterlogged, but the effluent from the tank apparently undergoes far less change through the action of the flood than the working of the filters. The tank is more elastic in dealing with variations in the quantity than are the filters.

2043. Have the tanks and filters ever been tested up to their maximum proportion of 3½ times the flow?—They have been tested up to more than that, sir; they have been tested up to 122,000 frequently.

2044. Well, that would be 3½ times?—That would be 3½ times, yes.

2045. Up to that proportion I understand you make no special provision for dealing with storm water; your tanks and filters will be sufficient to deal efficiently with the dry weather flow, and that volume of storm water?—That is so.

2046. Of course that remark applies only to domestic sewage?—To domestic sewage.

2047. Has there been sufficient experience of the treatment of sewage mixed with trade refuse and storm water to enable you to decide whether you can deal with that proportion?—It has not, sir. I am unable to give the results of experience on that point.

2048. Do you consider that the treatment in the septic

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tank is incomplete without the subsequent filtration?—I do.

2049. You would not advocate the provision of a septic tank and nothing else?—Except on conditions, such as a sea outlet or into an estuary.

2050. But only under these conditions?—Only under these conditions.

2051. Is there any nuisance likely to arise when the septic tank has to be emptied, and the sludge has to be removed?—Supposing that a tank is constructed in a town, of course you cannot be always selecting, I suppose, sites that are removed from houses. I am now referring to a place like Morecambe, where they are going to adopt the septic tank treatment before discharging sewage into the tideway, but that tank is surrounded by houses, and it has occurred to me whether a nuisance might not arise whenever the sludge from the tank had to be emptied?—The sediment itself is, unless warmed and stirred, practically inodorous, and drys quickly into a powder very like garden mould, and I anticipate no nuisance need be created in withdrawing it from the tank.

2052. Of course, by having your tanks underground you lose command, in certain situations, of land and possibly of filters also?—No; in the case of the tank, sir, there is no loss of head—practically no loss of head with the tank; the loss of head occurs at the filters. It flows out of the tank practically at the same level as it comes into it. That would be the level of the invert of the sewer—slightly above the level of the invert of the sewer. According to the depth of the filter so will the loss of head be. We found in Exeter from taps placed on No. 3 filter, so as to be able to draw off at every foot down, that the maximum purification took place at 3 feet, consequently I recommend that the filters should not now be more than 4 feet in depth.

2053. It is an essential part of your scheme that the tank should be underground, is it not?—No, not necessarily.

2054. Have you ever had them above ground?—Yes.

2055. Entirely above ground?—I think at Limpsfield and Oxted they are above ground, if I remember right, are proposed to be above ground.

2056. Why should you put them underground?—Usually the sewer is at that level, the tank will follow the level of the sewer.

2057. But there is no real necessity?—No.

2058. Except to allow the sewage to discharge into the tank by gravitation?—That is so; the most economical would be half under and half over.

2059. I do not know whether this is within your province to give an opinion about. How do you account for the aërobic action in Dibdin's filters being apparently sufficient to break up the sewage without the previous anaërobic action in the septic tank?—I do not know whether Mr. Dibdin contends that it is an aërobic action or not, but Dr. Rideal contends that it is an anaërobic action.

2060. In the filter?—In the filter, in the roughing filter, and Dr. Adeney's definition of anaërobic fermentation would also favour that view.

SEPTIC TANK SYSTEM.

SEWAGE TREATMENT.—COSTS OF INSTALLATIONS. Oct. 1898.

Place.	Population provided for.	Maximum flow daily.	Gallons treated daily.	Cost per head.	Cost per 1,000 gallons to be treated daily.	Cost of Maintenance per 1,000 gallons treated.
				s. d.	£ *s. d.*	*d.*
Exeter: St. Leonards -	1,500	Normal flow. 35,000	23·3	—	—	–
		Average flow. 54,000	36·0	—	—	·3
		Max. flow designed. 81,000	54·0	8 7½	8 – –	–
		Actual max. flow. 122,000	81·3	—	—	–
Exeter - - - -	47,000	2,500,000	53·2	6 4½	6 17 –	·05
Barrhead - - -	10,000	400,000	40·0	9 6	11 17 2	·13
Wallingford - - -	2,989	90,000	30·0	11 2	18 13 8	–
Warley - - - -	500	20,000	40·0	19 –	23 17 –	·33
St. Budeaux - - -	500	15,000	30·0	13 6	22 15 4	·40

EIGHTH DAY.

Wednesday, 19th October, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary*.

Mr. DONALD CAMERON, City Surveyor, Exeter, recalled; and further Examined.

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2061. (*Dr. Russell.*) I understood you to say that the sewage remained on an average from 18 to 20 hours in your tank; am I right?—The average of the year has been 24 hours in the tank. What I said was that the best results were obtained when the sewage remained in the tank from 18 to 20 hours.

2062. If we start with the conception of sewage as consisting of two parts, the fluid and the suspended solid matter, that hardly represents the true state of the case?—That is so. I mentioned that the deposit, both top and bottom, remained in the tank for a very much longer period—accumulate in the tank.

2063. In fact, they remain for an indefinite time?—That is so.

2064. So that the tank is what you may call a tank of deposit; it slows down the current of the sewage and enables the suspended matter to subside or form a scum on top?—Yes.

2065. And thereafter continuously goes through certain processes?—Yes.

2066. Which result in the solution of the greater part of the organic matter?—Yes, what Dr. Sims Woodhead calls a decomposition of the solid matters in the sewage. I think he says a decomposition not of a putrefactive nature. If I remember rightly he said that the decomposition that takes place was not necessarily a putrefactive process.

2067. And you made a very interesting observation that the scum thinned off in the summer time with the increased activity of the process of decomposition?—Yes, and that was also the case of the experimental tank which was resting; the first experimental tank when resting, when stopped from working, after a while the scum disappeared altogether. In the case of Yeovil, where the action is very much more rapid, till quite recently no scum was formed at all, but only a film.

2068. So that any defect in seasonal activity arising from temperature is equalised and made up by an excess in favouring circumstances of warm weather probably?—Yes; that is another of the smoothing influences of the tank, of storing during cold or wintry weather, and then a more rapid decomposition during warm weather. I may say that all the temperatures I have got of the inside of the tank are more uniform than those of the external atmosphere.

2069. So that the best theoretical result that you can hope for from your tank is that the speed should be such as to permit of the subsidence of this suspended matter, or at any rate, of its stratification. You can work your tank at as high a rate as you please, provided it allows the suspended matter to stratify itself?—That is so. From the observations that were made of the tank at Exeter, I have come to the conclusion that it is too large for the work it has to do, and that is confirmed by Dr. Rideal's analysis, when he found traces of nitrates in the tank effluent, that is, that the tank was doing work which should really be done by the filter. The reason of its being so large is the attempt to deal with a certain amount of storm water as well as the normal sewage.

2070. These tanks are of historical interest to my mind, because it reminds me of what was called the "sewer of deposit," and I suppose it shows that there is some good really in a sewer of deposit, or, at any rate, some elements of good, that can be followed up and worked out with success in such a method as you have adopted?—I always looked upon the smell arising from a manhole as being caused by a decomposing deposit in the immediate vicinity, and I have always looked upon that as objectionable, and provided flushing apparatus for removing it instead of ventilating apparatus for diffusing the gas in the town. In a trunk sewer there is a certain amount of decomposition going on undoubtedly.

2071. So that it is simply owing to the length of flow through a sewer. If the sewage of a town happened to flow to works for a mile or two—if you can imagine such a thing for the present purpose—then the sewage would be more nearly in the state which you aim at than if it were taken immediately the intercepting sewer began?—I conclude that less stay in a tank would be necessary under such conditions.

2072. Then you mentioned this matter of odour. I have got here an article entitled "Massachusetts Experiment on the Purification of Fresh, Stale, and Septic Sewage," by H. W. Clarke, who is the chemist to the State Board of Health of Massachusetts, attached to the famous experimental works at Lawrence, and I see he states that the sewage as drawn from their experimental tank, constructed according to what he believed to be the new system, had an abominable odour; the sewage, after its stay in the tank, is, when drawn from it, of an exceedingly offensive odour; quite highly coloured, but clear for sewage, and containing a relatively small amount of matters in suspension." How do you account for that happening?—I conclude that in that case the sewage was detained for a longer period than is necessary in the tank. In Exeter, when the tank is doing what is more nearly its proper amount of work, the only odour discernible is at the outlet. When the manhole covers are taken off the top of the tank very little smell is discernible, but at the outlet there is a decidedly ammoniacal smell, which I think Professor Ramsay concluded was sulphate of ammonia, but that is never so intense as to be a nuisance. I think the best evidence of that is that for the whole year the aërator was open to the atmosphere within a few yards of the public thoroughfare and within 70 yards of a large house.

2073. I have little doubt from what I hear from my brother Commissioners about their observations at Exeter, and what you have said, that you have certainly produced, so far, no nuisance; but I wanted to point out that it was possible to treat sewage, in a manner, on this new system, so as to produce a foul odour?—Yes.

2074. And your suggestion is that it is kept too long in the tank?—Yes.

2075. I think that is probably correct, because I see here it says that the sewage remains in the tank from twenty-four to thirty-six hours?—I may say that that same odour, that offensive odour, was found in Exeter before the filters were completed—fourteen days before, the tank was filled so as to let it form, to let fermentation go on, and when the first liquor was drawn from the tank it was extremely offensive.

2076. I see that this chemist also says that when the effluent was run upon ordinary intermittent filters containing five feet in depth of sand, the filtrate had a very foul smell, whereas when it was run upon a bacterial filter containing five feet in depth of small pieces of coke it produced a filtrate which was entirely free from smell?—From the experiments made in Exeter we found that nitrification with coarse gravel was less than that of sand, but both results were much inferior from that obtained from the coke or the clinker.

2077. Do you not think that the production of an odourless effluent from the tank depends upon the rate at which the fluid part flows away in some measure?—I think it altogether depends upon the stay of the sewage in the tank. I think it may be accepted that there is complete diffusion in the tank. That question arose, and was tried, by introducing colouring matter into the tank, and it was found that the colouring matter discharged from the tank at the time when the sewage with which it was mixed should appear at the outlet.

2078. The suggestion that the rate of flow varied would explain why it is that keeping it too long produced a foul effluent?—I take it in that report they retained the sewage altogether entirely in the tank—closed up in the tank.

2079. Yes, that is so; it is not a moving body of liquid. He does not explain the matter, but it strikes me that that must be the case. Another historical point of interest is that this practically amounts to making the sewage as stale as possible before bringing it to the place of final treatment, whereas if I mistake not, we used to be told that the fresher the sewage was brought to the place of treatment, the better it was for agricultural purposes?—Yes, but in Exeter the sewage is very fresh as it comes to the tank; it is a short distance, with rapid falls.

2080. So that your tanks have to do really all the work?—All the work, practically.

2081. Whereas in some places a good deal of it would be done by intercepting sewers?—Before it arrives at the works.

2082. I understood you to say that owing to the variable flow of the sewage, and the fact that the sewage must be worked off as it comes, the resting in the filters varies?—Yes.

2083. Does that affect the character of the effluent, or not?—It affects the character of the filtrate only.

2084. I beg your pardon, I desired to use the word "filtrate"?—It does not appear to interfere with the tank in any way, but during the five hours of night when there is practically no flow, a filter takes a long time to fill, and the one that has been filled is standing full also for a long time.

2085. Do you get a better filtrate in the circumstances of the slow?—No, we get a worse filtrate. The effect of a quick filling of the filters—that is, when they are filled in an hour or an hour and forty minutes—is such that the water capacity of the filters almost goes down with a run—rapidly declines. Before the filter has had time to discharge, to get rid of the residual water in it, the next dose is upon it, and in that way it becomes waterlogged.

2086. You have told us that you had observed a reduction of 25 per cent. in the retentive capacity of the filters in two years?—In what I have been calling the water capacity, not in the sense in which the Massachusetts Board of Health used the term, but in the quantity of water they will take over and above the filtrant in the filter.

2087. That seems to me to be a very serious fact, and it must work out either, I should think, in increasing your plant, or in increasing the size of your filters, or diminishing the time?—Yes, but I showed that if these filters were drained—if they were properly drained—that

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capacity would be very much increased. A filter after a day's rest and drained out will take a thousand gallons more, would take 1-6th more when filled again than it would take if the draining is not carried out.

2088. That, of course, comes back again to the amount of work you get out of your filters?—Yes, in consequence of the arrangements that I have got here, whereby the valve of one filter must be shut when the adjoining filter is filling, it prevents the draining of the filter during that period.

2089. Then a very interesting and very important matter is the character of the material you use for the filter beds. You have found clinkers to be the best?—Yes.

2090. Can you express generally what is the principle that is at the bottom of the efficacy of different materials for that purpose?—I think coal when broken cubically, with fine, straight, smooth surfaces, or a spar, gives, in my opinion, the ideal surface for filtration. From the small experiments I have tried I have got very good results from smooth surfaces laid dead level, that could be flushed and semi-dried alternately. The sewage coming into contact with that surface had a very high purifying effect upon it. And I think the filtrant that will give these surfaces, without containing any little caves that will hold the water, is the filtrant that gives the best filtrate.

2091. You think it is more the character of the surfaces of each individual element, so to speak, in the filter, rather than the intimate nature, the character, the porosity of the particle itself?—I think the filtrant acts purely mechanically; you simply require to produce a surface for the water to flow over. I believe greatly in the uniformity of the material. It, of course, increases the expense very much to get a uniform size of filtrant. I find that a filter of fine sand 3ft. deep, and a square foot in surface, or three cubic feet, will hold almost full of water when the sand is very fine, and is in such a condition that when a drop is put on the surface a similar drop will fall from the outlet; the balance is almost perfect. Then, of course, as the filtrant is coarser, if it is ⅛in., almost the whole of the quantity put on the filter will disappear in a few minutes, about 16 per cent. being held by capillary attraction.

2092. I noticed that you referred to an instalment on your principles at Barrhead, which is a village near Glasgow?—Yes.

2093. Is it complete—in progress?—The tanks are complete and in work, and I think four out of the number of filters are also at work.

2094. (*Colonel Harding.*) Since what date?—That I cannot tell you; I think, last week.

2095. Oh, quite recently?—They were in work last Friday, but when they were started I am not aware.

2096. (*Dr. Russell.*) Are these works to treat the whole sewage of Barrhead?—Yes; to deal with a population of 10,000 persons.

2097. And they include both filters and tank?—Yes.

2098. (*Professor Ramsay.*) I was merely going to ask, Are there not a great many works at Barrhead, specially dyeing?—There are some bleach works there, but the samples of sewage that were sent from there showed a purely domestic sewage. I think they have to deal with their worst effluents to some extent before discharging them into the sewer. We were instructed not to take that into account.

2099. Then another question as regards Yeovil. Are you getting good results from Yeovil?—The results vary considerably. We have two coke filters there which have given, I think, bad results from the beginning, but the clinker filters have given very good results indeed, and the small experimental filters give a very beautiful filtrate. Those works, as I explained yesterday, were laid down by the Council of Yeovil for the purpose of seeing if such a sewage could be dealt with by this method.

2100. The manufacturing in Yeovil is chiefly glove-making, I understand?—That is so.

211. Is the effluent from the septic tank different from the effluent at Exeter?—It is browner, and smells higher, and absorbs about 10 parts of oxygen per 100,000.

2102. Is there solid matter suspended in it?—No. According to Mr. Naylor's report, who acts for the Somerset County Council, of the 137 grains that went into the tank, only two came out; the action there is undoubtedly very rapid.

2103. Is the final effluent after filtration fairly clear?—In some cases very clear, but the variations are very considerable.

2104. Do you attribute that to the coke filters?—I attributed that at first to the method of working the filters; they filled them slowly, and they were kept full too long. That has now been altered, and each filter is filled—they have been sub-divided; there were at first three filters—there are now six—and each filter is filled more rapidly, and kept standing only a definite period; it is then discharged completely and allowed to drain. But in advising the Yeovil Board they have been advised to go in for a double filtration, considering the foul sewage that has to be dealt with.

2105. The matter has not been dropped by them?—They have adopted it. They called in Mr. Dibdin and, I think, Dr. Rideal, to make analyses; I think both were called in.

2106. (*Sir Richard Thorne.*) I think you have before you a report containing the chemical analyses, it follows Dr. Rideal's and Dr. Dupré's reports?—Yes.

2107. Will you kindly turn to the appendices to Dr. Rideal's report and look at Table 2 for a moment—dealing with the analyses of tank effluents? I notice there that the oxygen absorbed in sample No. 8 was 3·68 per 100,000, and that in No. 6 sample it is 7·04. That is so, is it not?—No. 6 is 7·04 and 6·82.

2103. Then if you look at the total ammonia, it ranges again between 4·0 and 7·0, does it not?—4·0 and 7·0.

2109. With regard to free ammonia, the range is between 3·5 and 6·25?—Yes.

2110. Now if you kindly look a little further on at the tables which follow Dr. Dupré's Further Report, you will see in Table No. 1, tank effluents, the range of the oxygen absorbed is from 1·7 to 3·08?—Yes.

2111. And the range with regard to ammonia is from 4·25 to 12·50?—Yes.

2112. And organic nitrogen from 1·80 to 7·75?—1·80.

2113. I do not quote any others, but these, of course, exhibit from a chemical point of view, very wide ranges, do they not?—They do.

2114. Could you give the Commission any idea as to why there is this very considerable variation in the degree of purification as viewed from the chemical standpoint?—The samples, if I remember rightly, were taken at the same time for the chemists; it was during November, and during, if I remember, wet weather. I think the samples were identical.

2115. That makes it the more striking, does it not?—Yes, that is so.

2116. (*Professor Ramsay.*) Are they identical? The first samples, Dr. Rideal's, were taken on November 4th and 5th; Dr. Dupré's on November 16th and 25th?—No, there must have been a second collection.

2117. (*Sir Richard Thorne.*) My only point is, could you give the Commission any idea why there should be this wide variation in the chemical constituents of the tank effluents?—No, I cannot.

2118. May I ask you a further question? If you look at Table No. 4, following Dr. Rideal's reports, you will see that there is a similar variation in the analyses of the raw sewages. Take, for example, oxygen consumed, the variation is very wide, from 0·74 to 4·92. I would ask, is it possible that this may be due to variations in the quality of the raw sewage?—Undoubtedly; I think that may be assumed.

2119. Have you any idea what that variation in the raw sewage is which requires a so much larger consumption of oxygen consumed, in some cases to what it does in others?—I have not got my rainfall table with me; probably that would explain it. I believe it to be due to the amount of rainfall at the time.

2120. Do you mean that excessive rainfall dilutes it so much that it requires less oxygen consumed, or that the excessive rainfall so interferes with the operation of the tank that it requires more?—The first. I should like to mention, in connection with that, that I have seen a great deal of samples taken while these works were going on by different persons, especially medical officers of health. I saw a sample taken by a medical officer of health for one of the Midland counties and analysed by the county analyst of Leicester, and from the sample taken—it was a "catch" sample.

2121. A what sample?—A "catch" sample, not over a period, but a single sample taken up. From the manner

in which the sample was taken I saw that it would shew a very strong sewage. The albuminoid ammonia in that case came out to the same as Dr. Dupré's.

2122. Was that sewage or the tank effluent?—That was sewage.

2123. I am not going to ask you any questions on bacteriology, as you have already said you do not wish to give evidence on that point, but have any experiments been made with the tank effluent or the nitrate at Exeter with regard to the organisms of typhoid bacilli?—Experiments were carried out by Dr. Pickard, of Exeter, on the behaviour of the typhoid bacillus in the raw sewage and in the tank effluent, on the influence of the raw sewage on the bacillus, and of the tank effluent on the bacillus. If I remember rightly his report is contained in the evidence submitted at the Local Government Board inquiry.

2124. Would you kindly tell me also whether any experiments have been made with regard to the influence of micro-organisms which are involved in putrefactive processes upon the water of the Exe after the filtrate reaches the river?—Yes.

2125. Where are they to be found?—In Dr. Sims Woodhead's report.

2126. I am not quite sure that I understood your evidence with regard to the storm overflows. Am I right in assuming that when once the sewer is full to its whole capacity its whole contents would be allowed to run away to the Exe?—No; what I meant to convey was this, and I may describe it with regard to the present practice: At present storm overflows are put on the sewers at a certain level, so that when the sewer becomes full, or nearly full, the surplus discharges into the streams. That, of course, depends upon the rate of flow at that moment in the sewer. What I suggest as a better practice would be to place these storm overflows still higher, considerably higher, so that the sewer would need to be under a head or pressure before any would flow into the river, and that the sewage, as much as the sewers could carry under these circumstances, should be conveyed to the works. It does not add very greatly to the expense of the sewers to increase the diameters by the small quantity that would be required to convey the whole of the contents into the works, into a storage there provided. As the storage fills up it will interfere with the flow of the sewers, and as it comes to the full head it would cause the surplus, or the surplus over and above what the works would deal with, to go into the river. The first washings would be provided for, would be got into the tank, and the subsequent part of the storm would be partly discharged into the stream. Such a storm overflow would be independent of the rate of flow in the sewers, but would depend upon the using up of the storage capacity provided.

2127. Your table which shows the maximum of the flow of sewage indicates that that takes place some time about half-past ten or eleven in the morning. At that time the maximum amount of sewage is flowing down the sewers, and the sewage would practically all go from that tank into the river, would it not? Or, rather, let me put it in this way: The material that went to the tank would be storm water plus the sewage which is flowing during its maximum flow, would it not?—These are the present conditions. *That* is when the sewage is at its maximum flow—or *that* period in the curve (*indicating a document*). A storm overflow placed at the apex of that curve would show that the mixture would be composed of 9 of sewage and 4½ of storm water, but in the case I have put, that period of maximum flow would be provided for in the tanks. If a storm should come at that period the tanks would take up that quantity, and it would spread the work over a certain number of hours.

2128. What would that excess consist of that would be used at the works?—A foot of storage for our tanks would give us——

2129. I do not mean in amount; what would be the material? Would it not be the storm water plus the sewage that has access to it during the maximum flow?—Undoubtedly it would; by that time the storm sewage would be much more dilute than the admixture at present discharged by storm overflows.

2130. In other words, you would simply rely upon dilution?—I would simply rely upon dilution. I do not suppose that any community could go to the expense of constructing works that would deal with the whole of the storm waters.

2131. I think you have explained to us pretty clearly that you are not satisfied with the filter effluent, when the contents stand in the filter for a long time, and especially during the night time?—I explained that even under those conditions, under the present conditions of working, none of the samples were distinctly bad. None of the samples of the filtrate even under those conditions were distinctly bad. I apprehend they would be materially improved were the conditions altered to more favourable.

2132. I suppose you have no standard as to what you mean by the word "bad"?—No; I go by appearance only.

2133. You have been asked several questions as to the reduction in the filter capacity after a filter has been in use some time?—Yes.

2134. I have not gathered—perhaps you have stated it in my absence—to what that reduction is due?—That reduction is undoubtedly due to the filtrant consolidating and to the formation of soil that takes place in the immediate surface. The tendency of the solid matter in suspension coming away from the tank is to form soil on the immediate surface of the filter.

2135. Not upon the particles of which the filter is composed, but merely on the surface area of the filter?—Undoubtedly these particles penetrate a certain depth, and if a weed, growing on the surface, is pulled up, all the rootlets carry part of the filtrant with them, and every one of the particles is surrounded by a substance like garden mould.

2136. But could you say whether there is a formation of anything upon the surface of the pieces of clinker of which the filter is composed to any substantial depth or not?—I explained that in two years two inches of the filter surface has had to be removed, especially during last winter. In the winter the accumulation cannot be dealt with as it can in the summer time. In the summer it dries and cakes on the surface, breaks up into cake-like piece; the rake takes all this off, but in the wet weather or cloudy weather in the winter time that accumulation lies heavy upon the surface of the filter.

2137. And does nothing interfere with the capacity of the filter below two inches of the surface?—I have no doubt that that must go further, but how far I am not able to say.

2138. (*Professor Ramsay.*) How do you determine the altered capacity of the filters?—By first filling them when dry, measuring the quantity as it went in when they were dry; then filling them a second time after a filter had been thoroughly wetted, and I took the second charge as the quantity of water that the filter would contain.

2139. Is it not possible that the clogging up of the filter is due to the growth of plant-like organisms in the interior?—Well, I attribute the discolouration that is observable at the first rush of the filtrate to the storage of either the organisms or their products being carried away by the filtrate—by the rush of the filtrate. That is the reason I think it is a distinct advantage, as it shows but very little alteration or variation on the general run from the filter as judged by the amount of oxygen consumed.

2140. But is it not possible that the experiment of draining a filter can be more readily made with a new filter so as to get its total capacity than with an old filter which acts like a sponge, owing to the organisms it has collected?—I tested the filter for that on Friday—it was tested by Dr. Dupré also—to see the quantity of that discharge, and to get a curve of the discharge. I got a glass tube attached to the lowermost tap of No. 3 filter, and took every minute the fall of water in the filter, and the curve that was got corresponded almost entirely with Dr. Dupré's previous experiment.

2141. (*Professor Foster.*) You have spoken just now of the organisms in the filter. Have they been examined?—Yes.

2142. Is there any report, so to speak, on the flora and fauna,—Dr. Sims Woodhead's.

2143. At different depths of the filter?—No.

2144. You speak of the organisms being "rushed" through?—He does speak of that; he took it from the filter. He took samples at different periods of the discharge and cultivated them.

2145. But no specimens have been taken from the substance of the filter itself?—No. The only estimation made in the body of the filter was for determining the amount of carbonic acid gas present.

2146. (*Chairman.*) I am not quite sure whether this question has been put to you or not; but I presume the filtrate has been kept and watched for a considerable period after it has been taken?—Yes, it has.

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2147. And has it been found that during that time it has developed either any matter or any bad smell?—On the contrary, without perceptibly depositing any appreciable quantity, it has clarified and produced no smell.

2148. And have you ever made an experiment whether a fish would live in it?—Yes.

2149. And have you found that they would?—Yes, gold fish will live in the filtrate.

2150. (*Colonel Harding.*) How long did your experiment last?—Almost from the very beginning; I should think from about Christmas, 1896. We began the experiments with the fish. I would have put a tank near the outfall if I had made the chamber a little larger, so that the fish could be placed there.

2151. (*Chairman.*) I just wanted to ask one more thing. Have you ever tried the effects of a second filtration; that is to say, have you ever tried letting the tank effluent go through a filter made of clinkers, and then through a filter made of something else?—I have tried the experiment of making it go through the filters at these works, and then going through the experimental filter. It showed a distinct improvement.

2152. It did show an improvement?—Yes. I look upon the question as altogether one of filtration; repeat the filtrations, and the results would continue to improve.

2153. You have not tried the second filtration at Yeovil?—No, except in the same way by an experimental filter.

2154. And did you find improvement there too?—Very beautiful results indeed.

I should like to mention that these works at Exeter have been working day in and day out under all weathers; they have been doing the entire work of dealing with this sewage. A journal has been kept of the working, and that journal was submitted to Dr. Thompson before the inquiry at Exeter, and also in June, 1897, and every information that we have in that book was placed at his disposal. There is an impression abroad that these works are worked only under favourable circumstances, but such is far from being the case; they are worked in all weathers, no matter what the state of the weather, and they were only stopped when an experiment had to be carried out, and that only happened, I think, three times in the year.

2155. (*Dr. Russell.*) I think you said yesterday that in the case of a town on the margin of the sea, or having the sea to discharge into, you think it might be possible to discharge the effluent from the tank right away?—Yes, undoubtedly all the offensive solids would be held back by the tank, and all that would come out would be the small particles that are visible in the effluent at Exeter, which would cause in a sea outlet no inconvenience whatever.

2156. If you had a town which was adopting a system of precipitation, and proposing to run the effluent right away from the precipitating tanks into the sea, your contention is that the substitution of a system of septic tanks would be equally adequate?—I think it has been proved that a septic tank will do the work equal to the best form of precipitation, will do work equal to the best work of a precipitating system.

2157. And, of course, there is the great economical advantage from the point of view of the local authority of having no difficulty with sludge?—Yes, and there is a further advantage as well, it has been proved, by Mr. Thudichum, that any sewage which is deprived of its organisms by chemicals must become putrid before it can become pure.

2158. So that the effluent from the precipitating tanks would not be so stable as the effluent from your septic tank?—The effluent from the precipitating tanks is stable to a certain extent; more stable than the effluent from the septic tank, which is in a very unstable condition—the smell from the effluent very quickly disappears. It has been observed by several people that from the time it comes out from the aerator here on plan to the furthest away filter the smell has almost entirely disappeared, and whatever is done to the effluent, however it is treated, the tendency is to become pure if allowed to absorb air.

2159. So that the effluent from precipitation tanks would be more liable to putrefactive change than your effluent; is that what you mean?—The effluent from the septic tank will not again set up putrefactive changes. The effluent from precipitation works will, if not carefully carried out, undoubtedly set up after-fermentation.

2160. (*Professor Ramsay.*) I think this is a very important point, and ought to be drawn special attention to. In Mr. Cameron's system the putrefaction is done, whereas in an ordinary system it is not yet done, but has to go on after the effluent is discharged?—If putrefaction is not completed altogether, it has still gone on to such a degree that the tendency is to become pure.

2161. (*Professor Foster.*) Have any exact observations been made on the changes which are taking place in this purification of which you are speaking?—Chemical examinations only.

2162. That is to say, there has been a chemical examination at the moment it leaves your tank, and at the time it falls on to the filter?—No observations made upon that.

2163. No exact observations as to what the change is that you speak of as the change of purification?—No, but it is very evident to the senses.

2164. To the senses?—You are trusting to observation by the senses only, in the statement you have just made?—That is so.

2165. Speaking broadly, taking the two great changes as putrefactive and nitrifying, the nitrifying appears to begin directly it leaves the tank; that is what you mean?—That is what I mean.

Mr. William Joseph Dibdin, F.I.C., F.C.S., &c.; called in and Examined.

Mr. W. J. Dibdin, F.I.C., F.C.S. 19 Oct. 1898.

2166. (*Chairman.*) I think you are Dr. Dibdin, and the inventor of what is known as the Dibdin process?—In the first instance, if I may correct you, I am not "Dr." I am only plain "Mr.," and I do not aspire to the position of an inventor in this matter. I have carried out a series of investigations from time to time in my capacity as chemist to the old Metropolitan Board of Works and the London County Council, and also in my capacity as a member of the local authority at Sutton, and as a result of these investigations, certain results have arisen, certain facts have been ascertained; but I do not wish to put these forward in the nature of an invention of any particular system or process, but merely that the application of these facts has led up to a practical position which we have found to be of value and interest. But in the sense of being an inventor of any particular system, or having proprietary rights, or anything of that kind—I have nothing whatever to do with that at all. I do not appear before you in that character.

2167. But you have had many years' experience of these things?—Yes.

2168. And you have written reports for the London County Council?—Yes. If your lordship would allow me, I have prepared a proof of evidence setting out these facts very shortly, and if it would save time I should be pleased just to run through this and then to answer any questions as we go on that you may desire to ask. Then I would refer to certain diagrams which I have prepared, which will show at a glance a great many of the facts I propose to put before you, and I have asked Mr. Thudichum, who has been with me in carrying out these investigations since 1884, formerly as my assistant in London and at present as my partner, to accompany me, and with your permission I would ask that he should be present and be able to assist me by showing the points, if it would assist you, of what I have prepared.

2169. Certainly?—My statement is as follows:—

"The witness is a Fellow of the Institute of Chemistry and of the Chemical Society, etc. For fifteen years he held the position of Chief of the Chemical and Gas Department of the late Metropolitan Board of Works, and its successor, the London County Council. During that period he devised and carried out the existing process for the purification of the River Thames, and subsequently carried out very numerous experiments on the purification of sewage by biological methods at Barking Creek, or Northern Outfall, Works of the London County Council, and at the works of the Sutton (Surrey) Urban District Council, which experiments have now been extended in various directions and places. As a result of these the witness has been able to formulate the method known as the 'Sutton System,' by means of which crude sewage is treated directly by bacterial action with the resulting pro-

duction of an inodorous and non-putrefactive effluent which is obtainable at a minimum expenditure both in regard to a capital cost and working expenditure. The quality of the effluent is practically the same as that obtained on a farm working under the best conditions." I may say that I have put forward these first few pages in order that you may be able to follow exactly the history of the question, having had the whole of the facts before you.

"The Sutton system is an outcome of the results of the early experiments on the purification of the Thames which were conducted from 1882 onwards with a view to ascertaining whether it was possible to obtain freedom from nuisance from the river by utilising the life processes of the numerous minute organisms abounding in the river. For this purpose the solid matters in suspension in the sewage were precipitated in the most economical manner possible, and the supernatant water mixed with various volumes of river water, and then kept under observation daily for prolonged periods. Side by side with these similar samples were tested, but in which the settled sewage had been first treated with various substances, such as chloride of lime, carbolic acid, lime water, manganate and permanganates of potash and soda, sulphuric acid, etc. Very numerous estimations were also made of the degree of aeration of the sewage, and of the river water, not only off the outfalls, but at numerous points throughout the length of the river below Teddington Weir. As a result of the chemical and biological information thus obtained, it became very clear that the destruction of the foul matters in sewage was effected by living organisms acting in the presence of free oxygen, and in the absence of antiseptic substances such as carbolic acid, chloride of lime, etc. Also that the growth and development of the living organisms was greatly facilitated by the application of oxygen in the form of permanganate of soda, which not only acted as an immediate deodoriser, but rendered the character of the sewage less resistant to the growth of the various organisms. It, therefore, became evident that sewage could be economically purified by first removing the excess of solid impurity beyond that which the organisms in the river could cope with, and then discharging the remainder into the stream.

"The point at which it became evident that the life in the river was overtaxed was indicated by the degree of aeration of the water. When this was above fifty per cent. of the total possible quantity of oxygen (which may roughly be taken at two cubic inches per gallon), the water in every case remained sweet and free from objectionable odour. When this factor fell below twenty-five per cent., then it was evident that the condition of the water was in a critical state. If in winter, in consequence of the life action being comparatively dormant, no great harm would result from the tendency to putrefaction, but if this occurred in summer the greater rapidity of the life processes would cause the water to be overcrowded in regard to the quantity of oxygen dissolved, and thus available for the support of the aerobic organisms, and a putrefactive action might soon be looked for.

"Arising out of these facts the practical issue soon became apparent. To obtain the destruction of sewage matters in a manner at once both economical and effectual, it was evident that it must be submitted to the action of organisms preferably acting in the presence of free oxygen. It is true that the action of the putrefactive organisms acting in the absence of free oxygen does, as pointed out by the late Dr. Angus Smith, effect the destruction of organic refuse, and it is this process which is at work in all rivers and streams in which sewage turns black and stinks, an action which has of late years been brought into use by various investigators, and recognised as a 'Hydrolysis.' In these cases, however, the work has to be completed by destroying the anaerobic, or putrefactive organisms, and using in their place the aerobic organisms acting on the liquid in beds more or less similar in character to those initiated at Barking Creek (and referred to later on), and worked more or less on the same principle. On the question of the advantage of the use of the aerobic or the anaerobic organisms to effect the preliminary breaking down of the solid matters of the sewage there is much debate, but having regard to the witness's experience as to what takes place in the self-purification of a river, and the fact that in all cases where the putrefactive organisms are employed their work has to be completed by the aerobic organisms, he is of opinion that if the work can be entirely accomplished by the latter, and thus prevent the formation of objectionable gaseous products, it would be the preferable method.

"These views having been publicly enunciated in 1887, they were put more particularly to the test in America in connection with the experiments of the Massachusetts State Board of Health, and demonstrated to be correct. The Massachusetts State Board of Health did not commence their experiments until some nine months after a paper I read before the Institution of Civil Engineers in January, 1887, and I have reasons to believe that that document was in their hands. At all events, I wish to show the sequence of events; whether it was by A or by B matters not.

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"In 1892 the witness was able to carry the Massachusetts experiments still further. In that year the London County Council authorised the construction of the experimental filter beds at the Northern Outfall. The results of the experiments with these are set out in the accompanying schedule marked 1. This is a report which I made to the London County Council, and was reprinted by order of the Main Drainage Committee on the 26th September, 1895. The report is dated October, 1895, having been extended to include additional experiments. The work was continued and extended over five years, and not only fully confirmed the work of the Massachusetts Board, but carried it a stage further by showing that settled sewage could be effectually purified by treatment on a fine coke or 'pan' breeze bed at the rate of one million gallons per acre per day. Summarising the result of the work accomplished on the one-acre fine breeze bed between September, 1893, and November, 1896, it appears that five hundred million gallons of settled sewage were treated. Since the sewage, which was passed on to the filter, contained on average seven grains of suspended matter per gallon, a quantity equal to 2,232 tons of sludge, of ninety per cent. moisture, had been entirely removed, the filtrates being practically free from suspended matter. Of the matter thus removed about 110 tons were organic (estimated dry), the whole of which had been oxidised, whilst the sand amounted to about forty tons, which, calculated at 24 cwt. per cubic yard, would cover the filter to a depth of 0·267 inch if spread equally over its surface. Such sand, however, had been carried into the body of the bed, and after three years there was no sign of its presence, and no danger of choking has arisen from this cause. The organic matters in solution in the effluent absorbed on an average 3·5 grains per gallon of oxygen from permanganate in four hours, whilst the filtrate absorbed only 0·7 grain. The amount of oxidation effected, measured in this way, would require ninety tons of oxygen. The organic matter in solution completely removed, as determined by the difference between the loss on ignition of the solids in the crude settled sewage, and the filtrate amounted to 250 tons, making with the 110 tons of suspended organic matter a total of 360 tons.

"These conclusions pointed most clearly and definitely to the greater question, viz.: that if the organisms had been able to accomplish so much work on the finer solid matters in the sewage, why should they not be equally potent for the destruction of the larger particles which in the aggregate form what is known as 'sludge'? It was evident that if these coarser matters were placed upon the fine bed they would speedily accumulate on the surface and form a deposit of putrefying matter. They must be enabled to penetrate into the mass of the bed, and this could be accomplished by making the bed with coarse particles of coke, ballast, etc., the interstitial space between which would form channels through which the sewage would flow, carrying with it the suspended particles. When the bed was full these would settle on the fragment of coke immediately below them, or be attracted to the side of the nearest mass, and there be subjected to the action of the bacteria and other low forms of life, which would in due course ultimately effect their complete destruction.

"Whilst this could go on to a certain extent, it was also evident that, owing to the necessity for supplying the organisms with fresh oxygen from the air, the bed must be emptied periodically, and that this would have to be done before the whole of the work was accomplished; hence the necessity for the second, or fine bed, in which the work could be completed. These considerations led to the construction of the first coarse bacteria bed at Sutton, where the witness suggested it to the District Council (of the predecessors of which body he was a member). The suggestion was taken up, and the bed brought into use on November 20th, 1896, and it has continued to give satisfactory results up to the present time. Further confirmatory experience has since been gained by the results of extended trials of the system at Leeds, Blackburn, Aylesbury, and elsewhere; whilst the general interest taken in the question has revealed numerous instances where the same methods have been

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at work, but in a haphazard and unsystematic manner. Indeed, it is now clear that the success of all sewage farming operations, or what is generally known as "land treatment," is entirely due to the healthy aerobic working of microbic life, and that when Dr.—now Sir—Edward Frankland introduced his system of downward intermittent filtration, the success of the method was due to bacterial action. The following comparison of results obtained by sewage farms and the Sutton bacteria beds will show the work accomplished by the latter, which in respect to the degree of nitrification especially, is decidedly superior.

"Sixth Report. Rivers Pollution Commission, p. 57."

"Average Land Drainage Water from Sewage Farms.

Average Organic Carbon -	0·982	pts. per 100,000
" " Nitrogen -	0·191	" "
" Nitrogen as nitrates, &c.	0·756	" "

"Sutton Effluent from Fine Bed.

Average Organic Carbon -	1·016	" "
" " Nitrogen -	0·172	" "
" Nitrogen as nitrates, &c.	2·19	" "

"Rivers Pollution Commission Standard for Effluents.

Organic Carbon - - -	2·000	pts. per 100,000
" Nitrogen - -	0·300	" "

"The effluents obtained at Sutton from strong 'separate system' sewage were therefore comparable with those obtained from average sewage farms, and contained only about one-half the quantity of organic carbon and nitrogen considered as permissible in a good effluent by the Rivers Pollution Commission.

"This result is, indeed, not remarkable when the nature of the conditions is considered. With the view of putting the question as clearly as possible before the Commission, the witness has prepared four diagrammatic drawings—A, B, C, and D. These diagrams represent by the length of the columns the degree of purification effected by coarse beds charged with different materials."

Appendix No. 15 (A, B, C, D).

2170. (*Professor Ramsay.*) What is that percentage of removals?—*This* (*indicating on diagram*) represents 100, and *these* represent the percentage removed. Diagram A shows the process which the sewage undergoes in its treatment on clay land with immediate sub-surface drains In this case the solids are retained on the surface, and the liquid passes almost immediately to the under drains with more or less imperfect purification.

"Diagram B shows the method of treatment on cultivated soil with under drains at about 18in. below the surface. Here the effect is necessarily greater than in the first instance, in consequence of the greater depth of soil, but undoubtedly the water will find its way more or less directly by channels into the drains, the extent of these fissures and channels determining the quantity of sewage which passes away imperfectly treated.

"Diagram C shows a similar state of things when the water is put on to a porous or gravelly soil deeply underdrained. For a while the results will be excellent, but in the course of time channels will be washed out and through these the effluent escapes.

"Diagram D shows the arrangement suggested for the more perfect treatment of the sewage by means of bacterial treatment. A certain quantity of the land is removed, and the sides and bottom of the 'tank' or hollow thus created may be puddled with clay, or concreted if on a very porous soil, to make it water-tight. Drainage pipes are then laid on the bottom, and the space is filled with some coarse material such as coke, clinker, broken granite, slates, chalk, burnt ballast, etc., coke, clinker, or ballast being preferred as having rougher surfaces, and entangling considerable quantities of air when the bed is refilled after standing empty. A penstock or sluice is fitted on the outlet drain in order to lock the sewage in the bed for a definite time as already explained. By this means the sewage is brought into contact with each particle of which the bed is composed instead of being allowed to find its way directly to the underdrains. When a sufficient time has elapsed the effluent is allowed to escape on to a similar bed at a lower level, but filled with fine materials. Here it undergoes the second "bacterial" treatment, and is ultimately discharged in a sufficiently purified condition.

Appendix No. 15 (E).

"A typical pair of beds is shown in diagram E. It will thus be seen that a coarse bed treatment of the crude unsettled sewage is really equivalent to broad irrigation; and that on the fine bed to effluent irrigation, but starting in this case with a better effluent than is usually obtained by means of chemicals, and thus the effluent from broad irrigation on a coarse bacteria bed is well fitted for the second treatment by effluent irrigation on a fine bacteria bed.

"From these considerations it will be seen that the 'bacterial process,' as the witness has termed the method which he worked out at Barking Creek and Sutton, is *land treatment*, but concentrated, accelerated and controlled, and therefore effective and economical, whilst 'land treatment' as generally practised is haphazard, uncertain, and expensive.

"The provision of land as a final safeguard may be met most completely by a third fine bacteria bed if desired. In other words by an area of land properly prepared and drained, and so arranged that all the effluents from the previous beds must pass through it, thus securing triple land treatment, but on an area of land considerably less than that usually employed.

"*The necessity for screening.*—In the case of broad irrigation either on ordinary land, or a specially prepared plot of land, called for convenience a 'bacteria bed,' the sewage should pass through a screen or screens to remove rags, etc. The quantity of matter so obtained from the Sutton Works is only twelve barrow loads per day, equal to thirty barrow loads per million gallons of sewage. The whole of these screenings have for six years been dug into a plot of land on which garden produce is grown. The work involved employs one man about one hour daily, and no nuisance of any sort is created.

"The suggestion to allow all these screenings to undergo putrefactive decomposition in a cesspool having an overflow, is carried into effect in certain cases with apparently successful results. Whether the screening and gardening, or the cesspool method be the best to employ further experience will doubtless demonstrate. The real point is that either method will answer the desired purpose, and the bacteria beds will completely do the rest of the work.

"The material of which these beds may be composed is almost unlimited. The great point is that the particles should be stable and difficult to break down by disintegration into a fine mud. For this reason coke, clinker, granite, flint, slate, etc., answer very well, whilst chalk has given excellent results. The original fine beds at Barking Creek and Sutton are composed of coke, or 'pan' breeze, sand, and burnt clay respectively; and the original coarse bed at Sutton was filled with burnt ballast, and has been in constant use for two years, the fine beds having been in use for six years, and in each case they are in as good condition as when they were started.

"Diagrams J1 to 4 show the percentage of purification effected by beds filled with the various substances mentioned.

Appendix No. 15 (J 1 to J 4).

"The witness, in conjunction with Mr. Thudichum, has recently made a special series of experiments with coke, coal and glass, with a view to ascertaining not only the purification effected by each, but also the water capacity of the beds, this being a matter of great importance as determining the area of bed required to deal with a given volume of sewage. The three beds were similar in shape and size, and the materials were riddled through the same mesh, the sewage effluent placed on them being also the same for all three at each charging. From the following tables it will be seen that the results obtained from the use of coke breeze were greatly superior to those produced by coal or glass:—

FREE AMMONIA IN EFFLUENTS.

No. of Filling.	Coke.	Coal.	Glass.
4	1·05	2·65	—
6	0·88	1·89	2·27
10	1·23	2·73	3·06
13	1·57	2·52	2·83
17	6·30	8·45	7·40
21	—	—	—
25	—	—	—
29	—	—	—
33	—	—	—
37	0·76	0·97	1·60
41	0·18	0·77	1·23
58	0·63	1·26	1·47
62	1·26	1·47	1·89
66	1·34	0·67	1·68
70	0·36	0·63	1·43
Mean - - -	1·41	2·18	2·47

ALBUMINOID AMMONIA IN EFFLUENTS.

4	0·060	0·095	—
6	0·040	0·060	0·110
10	0·050	0·140	0·160
13	0·070	0·200	0·270
17	0·060	0·120	0·130
21	—	—	—
25	—	—	—
29	—	—	—
33	—	—	—
37	0·050	0·060	0·050
41	0·035	0·056	0·056
58	0·031	0·042	0·056
62	0·060	0·070	0·080
66	0·050	0·060	0·060
70	0·040	0·040	0·060
Mean - - -	0·050	0·086	0·103

OXYGEN ABSORBED IN 4 HOURS IN EFFLUENTS.

4	0·890	1·300	1·780
6	0·650	0·950	1·360
10	0·710	1·290	1·470
13	0·820	1·640	2·020
17	0·540	0·980	1·030
21	0·540	1·050	0·820
25	0·710	1·090	0·790
29	0·600	0·820	0·660
33	0·680	1·130	1·050
37	0·440	0·760	0·600
41	—	—	—
58	0·560	0·760	0·910
62	0.810	1·130	1·240
66	0·700	0·920	0·750
70	0·650	0·970	0·760
Mean - - -	0·660	1·060	1·090

Figures represent grains per gallon.

Taking the impurity in the coke breeze effluent as unity, the following ratios are arrived at:—

——	Coke.	Coal.	Glass.
Free Ammonia -	1·00	1·55	1·75
Albuminoid Ammonia.	1·00	1·72	2·06
Oxygen absorbed -	1·00	1·60	1·65

In this series the superiority of the coke breeze is plainly demonstrated, every possible care having been taken to ensure exactly similar conditions for all three beds.

The experiments regarding water capacity also placed coke first, the positions of glass and coal however being reversed from those shown in the table of quality. After many measurements, extending over 72 fillings of each bed, the water capacities were found to be as follows:—

Coke - 40·4 per cent. of normal cubic contents.
Glass - 39·0 „ „ „
Coal - 29·9 „ „ „

"In these experiments, therefore, the coke did not only produce a better result, but with the same total volume of bed purified more sewage as follows:—

Sewage purified by Coke being taken at 100;
then „ „ Glass equals „ 96·4;
and „ „ Coal „ „ 74·1.

"Put into other words, four acres of coal filter of a given depth would be required to treat the sewage which could be dealt with by three acres of coke breeze of the same depth.

"Having regard to these various results it is evident that the question of efficiency of a material resolves itself into the character of its surface; thus coal, etc., presents a minimum surface per unit area, whilst coke may be taken as affording a maximum surface for the same area.

"The size of grain which has been found to be most suitable for the coarse beds is that which will pass, say, a four-inch mesh and be rejected by a half-inch mesh, *i.e.*, ordinary coarse coke or the coarsest burnt ballast. For the fine beds that which has passed a half-inch mesh, or better still, a three-eighth inch mesh, and been rejected by a one-sixteenth inch mesh to remove dust, which would otherwise prevent the proper aeration of the bed in consequence of its holding the water by capillary attraction.

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"If a third bed had to be provided this would doubtless be best formed in the manner found to be most efficacious by the water companies, as there would be no solids in suspension to deal with, and the oxygen dissolved in the water would probably in most ordinary cases suffice to keep the beds in order.

"The quantity of sewage which can be treated on these beds was ascertained in the first instance at Barking Creek, where the one-acre fine bed treated chemical effluent at the rate of one million gallons of sewage per day, the bed being three feet deep. At Sutton the coarse bed, having originally a similar depth, treated screened sewage without chemical treatment at the same rate, but prolonged experience points to a working rate, including all rest periods of three quarters of a million gallons per acre per day. This was with strong domestic sewage collected on the separate system. A larger quantity of weak sewage could be treated on the same beds. At Leeds, where the sewage contains quantities of manufacturing refuse, including solutions of iron salts which absorb large quantities of oxygen, the same rate was maintained from January to June on a four and a-half feet bed, viz., 770,000 gallons daily per acre, against 773.000 gallons at Sutton on a 3ft. 6in. bed.

The following table of the number of times the Coarse Bed at Leeds was filled; the liquid capacity of the bed at various dates; and the average temperature of the atmosphere and that of the bed will place these facts in a concise form before the Commissioners. The measurements are from gaugings taken by the City Engineer, Mr. Hewson:—

LEEDS COARSE BED.

Table of Capacity (Water) and Temperatures.
Bed first charged 1st October 1897.
Original Capacity - - 174,813 gallons.
Liquid Capacity - - 83,330 „

Date.	Filling.	Liquid Capacity.	Average Temperature during interims of Measurements.	
			Air.	Bed.
1897:	Two fillings per day.			
2 Dec. -	115	63,448	—	—
16 „ -	142	58,851	39½ deg.	50½ deg.
	Three fillings per day.			
30 Dec.	183	57,144	40 deg.	53 deg.
1898.				
13 Jan. -	224	51,160	44¾ „	53¾ „
27 „ -	265	45,423	44¾ „	54¾ „
18 Feb.* -	286	55,923	46 „	56 „
2 Mar. -	321	52,137	34 „	53¾ „
14 „ -	345	52,318	37½ „	55¾ „
26 „ -	380	46,154	43 „	56 „
9 Apr. -	421	42,979	43 „	52 „
6 May -	Returned to two fillings per day.			
14 June -	552	—	—	80 „
16 „ -	—	43,000	—	—
Bed rested from 16th June to 25th July for the building of a culvert alongside in connection with the extension of the beds. Re-started on 25th July at two fillings a day.				
28 July -	—	56,000	—	—
11 Aug. -	586	45,850	—	—
25 „ -	614	42,460	—	—
8 Sept. -	640	40,995	—	—
	Settled sewage only then put on bed (one hour).			
12 Sept. -	648	46,989	—	—
6 Oct. -	696	46,890	—	—
	Sewage settled half-hour.			

* 285th filling. 18th February. Before charging the bottom temperature was 77 deg., air 38½ deg., sewage 58 deg. as put on. After being full one hour 64 deg.; when empty the temperature rose to 66 deg.

286th filling. Before commencing filling air stood at 40 deg., and at bottom of the bacteria bed at 59 deg.; when the bed was charged its temperature was 56 deg., but after resting, charged two hours, it rose to 62 deg.

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2171. (*Colonel Harding.*) Have you the temperature of the bed during the long rest?—No; I have not got that here. I did not consider that so much of importance, as it occurred in June. The great and important point is to ascertain whether there was any marked increase in temperature in the bed during the winter weather, because that points to the one important factor in regard to the working of the bed during heavy frosts. If we have this bed behaving as a big hot bed which it evidently is, then there is no fear when it is being filled that we shall have any freezing, and other experience points to the same thing. I have not the figures for June, but no doubt Mr. Hewson will supply them.

2172. (*Sir Richard Thorne.*) Have you any evidence as to actual frost. Those figures you have given us do not go down to 32°?—I will refer to that if you please.

2173. (*Mr. Killick.*) Many of the trade effluents are warm when they are turned into the sewers?—I understand that is so, but in this case the temperature of the bed was above that of the sewage, and when the latter was first put in it went down and then up again.

2174. In a wool manufacturing town there is a great deal of hot water turned into the sewers?—Quite so, but in the case of Sutton there is nothing of that kind, and in the case of London there is very little in comparison with the volume of sewage. I will now deal further with the temperature question.

"*Temperature.*—The greater number of micro-organisms can only flourish within a very small thermometric range, namely, from about 50° Fah. to 100° Fah. It will be seen at once how important this factor is, in view of the fact that artificial warming of a sewage purification plant is practically impossible, owing to the great expense involved. The effect of the seasons upon the process going on in a bacteria bed or a septic tank forms a most interesting study. The experiments made by the Massachusetts authorities first showed that organic matter was stored in the filter bed in the winter months and destroyed by nitrification as the atmospheric temperature increased with the coming spring. The witness has shown elsewhere how, in the case of the septic tank, the amount of free ammonia is increased in cold weather, owing to the inability of the organisms to carry the process further; whilst, in summer, in spite of the destruction of the suspended organic impurities, the free ammonia is reduced in quantity.

"The problem of keeping the temperature of the beds well above the freezing point is partly solved by the sewage itself being, in the winter time, considerably warmer than the external air. The action taking place in the body of the bacteria bed will also tend in the right direction. This is well illustrated in the foregoing table of the Leeds results, wherein it is shown that during the winter months the temperature of the bed was about ten degrees higher than that of the atmosphere, whilst on February 18th, just before the bed was charged, the temperature was as high as 77°, the atmosphere being only 38½°. The temperature of the sewage put on was 58°, and after standing in the bed for one hour it rose to 64°. A further point, so far as the Sutton system is concerned, is the short time during which the sewage must be submitted to bacterial influences; since the whole process occupies only a few hours in each bed, there is no time for such a bulk of sewage to cool down appreciably. Effluent from the septic tank at Exeter, entering the bacteria beds at a temperature of 47·3° Fah. on an average, escaped at 48° Fah.; this was in the early part of April, 1897, the weather being very cold with frequent snowstorms. Judging from the experience gained in the Massachusetts trials and at Barking, Sutton, and Exeter, it does not appear that there is danger of the temperature of bacteria beds in this country falling to a point sufficiently low to destroy the vitality of the organisms. Thus in the case of Massachusetts, although there was ice over the surface of the filters during a considerable period, yet a good effluent was constantly produced; the chief effect observed was the non-production of nitric acid, which, however, was again formed when the warm weather returned, the nitrogenous matters having remained in great part stored in the filter. At Barking, during the severe frost of February, 1895, similar results were obtained, the filter continuing its work, although for six weeks it was covered with a sheet of ice, and the same result was experienced at Sutton, where the fine beds have been at work since 1892.

2175. (*Sir Richard Thorne.*) Could you put in the temperatures; the mere term "severe frost" carries nothing to our minds?—If you please I will refer to the record of temperatures of the Registrar-General.

2176. It would be convenient if we could get them in at that point; "snowstorm" means nothing?—The London County Council will probably allow me to supply the figures. We will put them in. The Commission will remember that that year was the most severe winter of the century, I think. In this connection it may be well to point out a danger that may arise from too careful distribution of the sewage over the surface of a bed; in such a case the incoming sewage itself may be frozen, and fail to penetrate the bed at all, as was actually the case with an experimental filter on another plan at Sutton, even during the extremely mild winter of 1897-8.

The question necessarily arises as to the most suitable depth for the beds. This, in the witness's experience, must be governed by the local conditions. As a general rule it will be more convenient to have them from 3ft. to 4ft. deep, but as at Leeds and Sutton, this may be exceeded, the coarse bed at Leeds being 4½ft. deep and the fine bed 5ft. deep, whilst at Sutton the coarse beds are now 5ft. deep, and the fine beds nearly 3ft. deep. At Blackburn both beds are 6ft. deep. The witness has carried out, in conjunction with Mr. Thudichum, laboratory experiments in a specially constructed filter arranged so that samples could be collected at every foot down to 8ft. deep, after the bed had been standing full for two hours, with the following results:—

OXYGEN ABSORBED IN FOUR HOURS.

No. of Filling.	1 Foot.	2 Feet.	3 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	8 Feet.
32	1·01	1·01	0·86	0·71	0·71	0·56	0·66	0·61
45	0·68	0·69	0·52	0·46	0·52	0·46	0·46	0·34
62	1·09	0·98	0·86	0·74	0·69	0·52	0·40	0·34
99	0·89	0·78	0·89	0·89	0·83	0·33	0·22	0·22
130	1·28	1·22	1·15	1·10	1·10	0·99	0·82	0·82
146	0·88	0·82	0·88	1·00	1·00	0·88	0·82	0·76
163	2·22	1·79	1·57	1·47	1·47	1·31	0·98	0·87
192	1·89	1·70	1·64	1·38	1·22	0·96	0·74	0·74
228	3·48	3·05	2·57	2·19	1·98	1·71	1·44	0·86

NITROGEN AS NITRITES AND NITRATES.

No. of Filling.	1 Foot.	2 Feet.	3 Feet.	4 Feet.	5 Feet.	6 Feet.	7 Feet.	8 Feet
32	0·00	0·00	0·00	T.	T.	0·08	0·10	0·30
45	0·00	0·00	0·00	T.	T.	0·12	0·14	0·22
62	0·00	0·00	0·00	0·00	0·00	T.	T.	H.T.
99	0·00	0·00	0·00	S.T.	T.	T.	H.T.	T.
130	0·00	0·00	0.00	0·09	0·23	0·31	0·46	0·64
146	0·02	0·03	0·06	0·32	0·21	0·25	0·35	0·25
163	0·24	0·08	T.	0·03	0·11	0·34	2·00	2·94
192	0·00	0·00	0·00	0·00	0·00	0·12	1·02	1·70
228	0·00	0·00	0·00	0·00	T.	T.	0·13	1·23

Figures are grains per gallon.
Abbreviations:—T.—Trace. H.T.—Heavy Trace. S.T.—Slight Trace.

"The general result is to show a better result in the lower depths than in the upper depths." To my surprise I found the indications to be in favour of a greater depth than a less one. "In this special matter of depth, however, it is difficult to produce in a laboratory conditions comparable with those obtaining outside, owing to the necessarily small diameter of the bed, and the, therefore, abnormally large proportion of side to body of filter. It may be, therefore, that the experiment, if repeated on working lines, would yield a very different result. The above table is put forward to show what was obtained, but must not at present be taken as expressing any definite views on the matter.

"*Light.*—The following series of experiments will prove interesting, as showing that the organisms chiefly concerned in the aerobic purification of sewage seem to be unaffected by conditions of light or darkness.

"Two vessels were taken, of similar shape and size, and filled with broken glass as a bed material; the one was left bare and fully exposed to the light, whilst the

other was covered all over with black light-proof paper and fitted with a cap of similar material. These, on being used as bacteria beds, all the conditions, except the exclusion of light, being precisely the same, yielded the following results:—

Number of Filling.	Light.			Dark.		
	Ammonia.		Oxygen absorbed in 4 hours.	Ammonia.		Oxygen absorbed in 4 hours.
	Free.	Albuminoid.		Free.	Albuminoid.	
25	-	-	0·82	-	-	0·76
29	-	-	0·71	-	-	0·60
33	-	-	1·03	-	-	1·08
37	1·64	0·06	0·65	1·47	0·05	0·55
41	1·23	0·056	-	1·23	0·056	-
58	1·47	0·056	0·91	1·47	0·056	0·91
62	1·68	0·07	1·24	1·89	0·08	1·24
66	1·68	0·07	0·75	1·68	0·06	0·75
70	1·47	0·06	0·76	1·39	0·06	0·76
Average	1·53	0·062	0·86	1·52	0·06	0·83

It will be seen that equally good results were obtained by either method. Having regard to the fact, however, that light could hardly be expected to penetrate far into the depth of a bed, or tank filled with dark coloured sewage, the point does not appear to be very material.

Reaction.—The most favourable condition of the sewage for bacterial activity is that of very slight alkalinity, a condition which occurs naturally in ordinary domestic sewage. Occasional variations, even though relatively large, appear to exert but little prejudicial influence, but a continuance of excess of either acid or alkali will put a bacteria bed out of action for a time. Sewage containing the highly acid liquor obtained from the preliminary treatment of iron for galvanising, will yield to a very considerable extent to bacterial influences; but if its use be continuous, the purification effected becomes gradually less, and the bed requires a prolonged period of rest. Very alkaline effluents, such as those produced by the use of lime in excessive quantities, are very liable to putrefy, instead of becoming purified by oxidising organisms.

"The oxidation of iron is, of course, effected by direct combination with the oxygen of the atmosphere, the bacteria playing but a small part, if any, in this process.

"In the case of the dilution of either acid or alkaline sewage a considerable number of re-actions are brought into play, with the result of more or less neutralising the deleterious action of the original crude liquor, and thus rendering it more susceptible to bacterial influences.

"*Time of Contact.*—This point constitutes the main difference between the system now known as the 'Sutton' and the method of intermittent downward filtration. It was found necessary for the sewage to be subjected to the action of microbes under proper conditions for a certain period of time; if this were not allowed, the purification was incomplete; when it was greatly exceeded, the aeration, and consequent recuperation, of the bed was affected disadvantageously. For this reason the bacteria beds are locked, and the sewage kept in them for a period of about two hours; the effluent being then allowed to escape, the undestroyed portion of the organic matter held in the empty bed is vigorously attacked by the organisms under the most favourable circumstances of combined dampness and air supply, and the bed is thus prepared for a further charge. The necessity for the locking has been proved by numerous experiments, from which also the most suitable average time limit has been arrived at.

"The work done during the empty period can be well demonstrated by taking samples of the drainings at intervals and estimating the amount of oxygen absorbed from permanganate and the quantity of nitric acid present. It will be found that the former factor steadily diminishes whilst the latter increases. For example, the various beds at Sutton gave these results, taking it from the time, 2.20 p.m., when the valve was first opened, to 3.22 p.m., the time of the last runnings from the filter." I have them at 2.20, 2.30, 2.40, 2.50, 3.0, 3.10, and 3.22 p.m.

TABLE OF RESULTS OF ANALYSES OF SAMPLES OF EFFLUENTS FROM No. 1 COKE BREEZE FILTER AT SUTTON, SURREY.

(Quantities stated in Grains per Gallon.)

Date of Collection.	Appearance.	Odour.	Reaction.	Chlorine.	Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as		Suspended Matters.	
					Free.	Albuminoid.	At once.	In four hours.	Nitrites.	Nitrates.	Total.	Volatile.
Oct. 15, 1898. 2.20 p.m. (when the valve was first opened).	Cl. & B.	Nil.	V.F.Alk	6·3	1·89	0·12	0·00	0·87	0·028	0·588	0·0	0·0
2.30 p.m. - -	„	„	„	6·2	1·51	0·17	0·06	0·70	Slt. Tr.	1·046	0·0	0·0
2.40 „ - -	„	„	„	6·4	1·60	0·07	0·06	0·64	„	0·882	0·0	0·0
2.50 „ - -	„	„	„	6·4	1·47	0·06	0·00	0·64	0·000	0·980	0·0	0·0
3.0 „ - -	„	„	„	6·3	1·55	0·06	0·00	0·64	0·000	1·046	0·0	0·0
3.10 „ - -	„	„	„	6·4	1·34	0·05	0·00	0·52	0·000	1·362	0·0	0·0
3.22 „ (last runnings from filter).	„	„	„	6·4	1·47	0·05	0·00	0·64	0·000	0·921	0·0	0·0

"That table shows us that as soon as the valve was opened we have a larger quantity of organic matter in the first rush of the bed than we have later on. That is a well-known fact, and in all instances of the action of filters the water which drains away at last is always the best, but as long as we get even the first flow to be of such a character that it affords no after putrefaction it is a question whether we have not effected all that is necessary. Then I have a further series of results of the samples from the Exeter Beds at Belleisle. There the results are as follows:—

Five minutes after opening valve.

Albuminoid - - - - -	0·100
Oxygen absorbed in 4 hours - -	0·280
Nitrogen as Nitrites - - - -	0·224
Nitrogen as Nitrates - - - -	0·290

One hour after practically empty.

Albuminoid ammonia - - - -	0·070
Oxygen absorbed in 4 hours - -	0·112
Nitrogen as Nitrites -	0·326
Nitrogen as Nitrates	0·499

Mr. W. J. Dibdin, 19 Oct. 898.

The falling of the oxygen absorbed figure is well shown in the following table :—

OXYGEN ABSORBED FROM PERMANGANATE IN FOUR HOURS BY SAMPLES TAKEN AT VARIOUS PERIODS DURING FILTER DISCHARGE, AT BELLEISLE, EXETER.

Minutes after Discharge.	14th October, 1897. Filter No. 2.	15th October, 1897. Filter No. 1.
2	0·400	0·372
5	0·395	—
15	0·360	0·305
25	0·251	—
30	—	0·214
35	0·214	—
45	0·210	0·203
55	0·157	—
60	—	0·136
65	0·140	—
75	0·134	0·125
85	0·130	—
90	—	0·210
95	0·130	—
105	0·126	0·125
115	0·120	—
125	0·120	—

Figures represent grains per gallon.

"Those tables show the same thing between the first discharge and the last that we had in the case of the beds at Sutton, and it points to more care being required to empty the beds, not to allow the first portion to rush out too rapidly." But still it does appear to me that the question of the bad effluent, as we may call it, although it is not really bad in itself, but only comparatively so, may be met by allowing all the effluents from all the beds to mix together on the surface of one common bed, and there pass through that, because the larger portion of this matter which comes through the bed is living organic matter, and when you include in your analyses the whole of the organic carbon, nitrogen, and so on of the living organisms, it seems to me it is hardly a fair way of determining the quantity of putrefactive sewage matter in the effluent from the sewage. It is not right to include living organisms and to call them sewage, because living organisms turned into a river must necessarily have a very different effect to that produced by turning in a putrefying organic matter. Therefore, it does seem to me that it would be a better way if it were desirable to separate these organisms, to let the whole of the effluents mix together, and then to soak through what I call a 'sand strainer' rather than a 'sand filter,' and by that means you would have one average of the whole of your effluents for the day.

"*Storm Water.*—It is one of the essential features of the bacterial bed system that when the normal sewage is largely diluted with rain water the beds may be worked at a far greater rate, as the work thrown upon them depends upon the quantity of true sewage matter, and not on the mere volume of water with which it is mixed. Thus, if the sewage is one-half of the normal strength the beds will deal with double the usual quantity. At Sutton the beds have frequently been filled six or seven times a day during wet weather.

"It is also important to point out that the beds may be considerably overworked for limited periods, if required, without their suffering permanent injury, as by resting they will speedily recover their original working capacity. They are in fact *digesters*. They work best when regularly fed, but are capable of reasonable variation. They can do more work in the summer than in the winter, as bacterial life is then more active, but as already shown even in the winter the process continues.

"*Trade Refuse.*—An advantage of the bacteria system is that refuse liquids from manufactories, etc., can be dealt with without nuisance or great expense. Of course the provision of two simple beds with or without a preliminary settlement may not always be sufficient, and in such cases suitable modifications in the application of the general principles of the system must be made. But these modifications will seldom present much difficulty, and so far as our present experience goes they are invariably successful. The results of work in this direction are embodied in a paper submitted to the Society of Chemical Industry on the 30th April last, a copy of which is submitted herewith, Schedule 2.

RESULTS OF WORK AT SUTTON, LEEDS, AYLESBURY, AND BLACKBURN.

"The analytical data showing the results of the work accomplished by the simple bacteria beds under different conditions are set out in the tables and diagrams F 1 to 4 to I 1 to 4 attached hereto, the tables being indicated by the same corresponding letter and number as the diagrams.

"The first set of these, viz., F 1 to 4, show the results of the working of the beds at Sutton, which deal with domestic sewage collected on the separate system. Set G 1 to 4 show the results obtained at the works of the Corporation of Leeds at Knostrop; the sewage in this case containing large quantities of manufacturing refuse, and especially salts of iron. Set H 1 to 4 contain the results of the work effected on a sewage containing a small admixture of trade refuse, viz., that of Aylesbury. Set I 1 to 4 show the work accomplished at Blackburn, the beds in this instance being 6ft. deep. Appendix No. 15 (F 1 to F 4). Appendix No. 15 (G 1 to G 4). Appendix No. 15 (H 1 to H 4). Appendix No. 15 (I 1 to I 4).

"Special experiments have also been made on the very refractory refuse from the northern distilleries with the most marked success. Special precautions had to be adopted, as in some instances the liquid treated was one hundred and fifty times the strength of normal sewage.

SUTTON.

"On examining these diagrams and the accompanying tables, on which they are based, it will be seen that at Sutton, from November, 1896, to August, 1898, the suspended matters were virtually all removed by the action of the coarse bed alone, and completely so after the effluent had passed through the fine bed.

"The effect of the double treatment was to reduce the free ammonia by 91·2 per cent.; whilst the organic matter in solution as judged by the albuminoid ammonia, was reduced by 80·2 per cent., a result confirmed by the oxygen absorbed in four hours' test.

"In the two latter diagrams (F 3 to 4) it will be noticed that the quantity of nitrogen as nitrates, etc., is indicated by a dotted line, and on inspection it will be seen that this factor gave a clear indication of the satisfactory or otherwise working of the beds. In May, 1897, the original experimental coarse bed (there are now four of these) was purposely overworked, with the view of ascertaining its maximum power. The result was that the organic constituents in the effluent rose very considerably, with a corresponding reduction in the oxidised nitrogen, thus confirming the experience gained in the month of March, 1897. Having thus gained a knowledge of what the beds could not do, they have been kept more systematically at work since then, with the consistently satisfactory results indicated." Appendix No. 15 (F 3 and F 4).

2177. That rise is in the second filter only?—In both, but more particularly in the second. The next series I have are the diagrams showing the results at Leeds. There is a similar sequence, but here the results are probably a good deal more uniform, because the daily samples would have made such an enormous mass of figures that I have taken the weekly averages of all the analyses made. If the Commission would like to have the actual daily results of the daily examinations, I shall be pleased to put them in, but I thought that for this purpose the average would perhaps be best. The sewage was only examined for a limited time, from October to December, and the results are indicated here, showing about 40 grains per gallon. Here we have the same general reduction; practically the whole of the suspended matter is removed, the greater part by the coarse bed, and practically the remainder by the fine.

LEEDS.

"Diagrams G 1 to 4, indicating the results obtained at Leeds, show the reduction of the suspended matters from about 40 grains in the sewage, to about 2 grains in the effluent from the fine bed. Of this quantity the large portion was due to oxides of iron, and the remainder consisted almost entirely of living organisms, such as minute worms and larvæ, etc. Appendix No. 15 (G 1 to G 4).

"The reduction of the free ammonia has been steadily maintained, whilst the organic matter, as measured by the albuminoid ammonia, has shown a fairly even rate of reduction similar in degree to the results at Sutton, a result confirmed, as in that case, by the 'oxygen absorbed' test.

"The quantity of nitrogen in the form of nitrates, etc., is indicated by the dotted lines, and again shows the similar characteristic, but in this instance, in consequence of the large quantity of iron in the sewage the nitrates are very low, as might be anticipated. This is one of the instances in which any standard based upon the nitrate factor would be utterly fallacious.

AYLESBURY.

Appendix No. 15 (H1 to H4).

"The same story is told again by the Aylesbury samples. At Aylesbury (diagrams H1 to 4) the experiments extended from January to June in the present year, with almost identical results. The suspended matters were removed; the free ammonia was reduced by 58·0 per cent.; the albuminoid ammonia was reduced by 70·9 per cent.; the oxygen absorbed by 67·9 per cent.

2178. (*Chairman.*) I think we must ask you to leave us this paper and these diagrams?—Yes.

2179. And we should ask you, if you do not mind, to come and see us again; we should like to digest all this?—I thought probably that if I put this—which is really a very long story if we go into details—into as concise a form as possible, it would suit your convenience, and when you had had time to further consider it, you might like to put questions to me.

2180. Yes, if you will allow us?—Yes. For that reason I am not entering into minute details and figures; I am rather leaving those for your further consideration when you have them before you.

"With reference to Aylesbury, it will be noticed that the reduction apparently effected by the fine bed was not so satisfactory as in some other cases, and this fact gave the witness much concern until it was ascertained that the pipe used to send the effluent pumped from the coarse bed to the fine was also employed in the interim to convey the sludge from the chemical precipitation tanks to the sludge beds, which were placed at a position further away from the pumping house than were the fine beds; and to economise plant the same pipe was inadvertently used for two purposes, with the result that sludge from the precipitation tanks found its way into the coarse bed effluent, and thus to the fine bed. As soon as this defect was remedied, the normal satisfactory effluents were obtained. The variation in the nitrates clearly indicated the cause of the trouble, and rendered its detection possible. This experience was but a repetition of that which occurred in connection with the original experiments at the Northern Outfall, Barking Creek, as detailed in the copy of the witnesses report to the Main Drainage Committee of the London County Council, and attached hereto (Schedule I.).

The instance I have given was a result of economy, but it is a very important thing, because it does indicate the changes which the beds are liable to, both in the quality of effluent and the corresponding behaviour of the nitrates, and it quite agrees with what I had on a former occasion. It does help us to explain anomalies; we do not know what goes on underground, and on the face of it there appears to be a failure, but where we have a clue we are able to indicate the fault, and in this case the clue is given here. Then I have the results at Blackburn.

BLACKBURN.

Appendix No. 15 (I1 to I4).

"The experience at Blackburn (diagrams I1 to I4) shows the same sequence, viz., suspended matters removed; free ammonia largely reduced; albuminoid ammonia reduced by 62·5 per cent.; and oxygen absorbed reduced by 65·0 per cent. Here, again, the nitrates varied with the degree of purification; but, as at Leeds, they were but small in quantity as compared with those at Sutton and Aylesbury; and this may be attributed to the fact that the supply of water to the city of Blackburn is very soft and free from lime. At Leeds, the same factor comes into play, but is accentuated by the large quantity of iron in the sewage.

2181. (*Colonel Harding.*) What is the Blackburn sewage; is it mere domestic sewage?—There is very little waste water or manufacturing refuse in it. It is mere domestic sewage, the waste water of ordinary manufacturing condensed water, and that sort of thing. They have not what they call manufacturing refuse liquor; they have some condensed water, and so on.

2182. (*Mr. Killick.*) They have paper works?—Yes, and so on.

2183. (*Colonel Harding.*) That at Aylesbury is dealing with domestic sewage also?—Yes, and there is a considerable quantity of milk washings. The next point, the last I have to trouble you with, has to deal with the question of cost, which I was particularly requested in the letter I received from your Secretary to mention. The initial cost of the Sutton bacterial system must necessarily vary according to the local conditions in each case. From what has been stated in reference to the comparison of the prepared beds with land treatment, it will be seen that where there is any reasonable fall from the main sewer to the outlet of the works the plant will be of the simplest character, being merely hollows in the natural soil, drained and filled with coke, etc., as already explained. At Sutton No. 7 bed was constructed in this manner. It has an area of one-tenth of an acre, is three feet deep, and cost less than £100. Such a bed filled with coarse material is capable of treating nearly 77,300 gallons per day. If this item is doubled for a corresponding fine bed, and, say, 20 per cent. added to allow for the greater area necessary in consequence of the difference in water capacity due to the use of a finer grained material, we have another £120, or £220 in all. If the beds are to be five feet deep, an additional £130 will be required for ballast, etc., to raise them from three to five feet, thus making a total of £340, for a pair of beds capable of fully treating 77,300 gallons of strong 'separate system' sewage daily This factor, obtained from actual results, equals £4 8s. per 1,000 gallons daily for first cost under favourable conditions. If more or less expensive brickwork is necessary, concrete, etc., then the cost will be increased proportionately, and may in some cases be more than double that item. In extreme cases it may be even more That is a point for the engineer. In the case of No 8 bed at Sutton, this was constructed by Mr. C Chambers Smith, the Surveyor, at a cost of 4d. per foot super, or £726 per acre, which considerably reduces the above estimate.

"The working cost is necessarily less as the volume of sewage increases, as the work of the attendant is practically limited to turning on the valves to divert the sewage into the respective beds, and to clearing the screens from time to time. One man, with the assistance of a labourer, would be able to attend to a plant treating half a million gallons of sewage per diem. Their united wages may be taken at £3 per week. This item will completely cover all current working expenses, as there are no royalties to pay, and works out at 0·206d. per thousand gallons treated. If the calculation is made upon, say, 2.000 000 gallons per day, the current expense would be not more than 0·103d., as we need only double the labour to deal with four times the sewage.

"In the case of the admixture of trade refuse with the sewage the area of the beds may, in some cases, be required to be proportionately larger and the working expenses consequently somewhat increased.

"The fact that some of the sewage of Leeds containing large quantities of manufacturing refuse has been successfully treated at rates, and on areas equal to those employed at Sutton tends to show that little increase in first cost and working expenses need be feared, beyond that due to the special local conditions in regard to nature of soil, differences of level, etc.

SCHEDULE 1.

LONDON COUNTY COUNCIL.

REPORT by the Chemist on the Experiments on the Filtration of Sewage Effluent during the years 1892-3-4-5.

(Reprinted, with addition, by order of the Main Drainage Committee, 26th September, 1895.)

To the Main Drainage Committee.

On the 10th of March, 1891, the Committee ordered a series of experiments to be conducted as to the best methods of filtering the sewage effluent obtained at the northern outfall precipitation works. After these had been carried out, with the result that coke-breeze was found to be the most suitable material for the purpose, the Committee, on the 24th of November, 1892, ordered that the experiments with that material should be resumed on a larger scale, the size of the new filter being one acre. In accordance with the order of the Committee of the 7th of March, 1895, I now submit the following statement of the methods of procedure and the results obtained.

From the foregoing it will be seen that the experiments may be conveniently divided into two main groups, viz.:

(1.) Experiments with small filters and various filtering materials.

(2.) Experiments with a 1-acre filter, using coke breeze only as material.

The latter may be again sub-divided into—

(*a*) Preliminary trials on velocity of passage, etc.

(*b*) Experiments on biological lines.

(*c*) Experiments with doubled means of filling.

(*d*) Experiments with increased facilities for emptying.

(*e*) Experiments on recuperative power.

19 Oct. 1892.

Series No. 1.

The tanks for filters used in the first series of experiments were built of wood, and were each equal in area to 1-200th part of an acre. They were four in number, and were filled with pea ballast, coke breeze, burnt clay, and a proprietary material (with gravel and sand) respectively. All four were worked at the same rates and during the same hours. During the first six weeks sewage effluent was passed through at the rate of 500 gallons per square yard per day, whilst from the middle of July to the end of August the rate was reduced to one-half, or 250 gallons per square yard in 24 hours. The filtration was intermittently continuous, the filters passing effluent constantly for 8 hours daily and resting during the remaining 16 hours, being allowed to run dry at the end of each day's work. The outlet valve was closed just sufficiently to keep the filters full, the effluent being level with the surface of the filter material.

Filter No. 1. Burnt Ballast.—The material for this filter was obtained by burning clay taken from the marsh land adjoining, and was placed in a tank to a depth of 4 feet, the larger pieces being laid at the bottom, and the remaining unsifted portions being placed above.

The whole quantity of effluent passed through amounted to 185,000 gallons, in a total of 2,160 hours, of which the filter worked 484 hours and rested empty 1,676 hours. The average rate, therefore, inclusive of rest periods, was 411,000 gallons per acre in 24 hours. The filtrate was sampled and analysed frequently, a sample of the crude effluent being also examined for the purposes of comparison, great care being taken that the two sets of samples corresponded, *i.e.*, that the filtrate analysed represented the crude effluent.

Date, 1892.	Oxygen absorbed in 4 hours.		Albuminoid ammonia.	
	Crude effluent.	Filtrate.	Crude effluent.	Filtrate.
14 June	3·311	1·897	—	—
15 „	2·154	1·615	—	—
17 „	1·909	1·431	—	—
21 „	2·255	1·244	·250	·170
24 „	2·205	·826	·230	·110
29 „	·890	·636	·150	·150
7 July	1·533	·805	·220	·070
8 „	1·330	1·260	·200	·120
11 „	1·624	1·120	·250	·140
13 „	1·230	·590	·380	·210
15 „	1·610	·952	·330	·140
18 „	2·611	1·043	·270	·160
20 „	1·260	1·050	·170	·120
22 „	2·415	1·372	·350	·110
10 August	2·198	·735	·230	·100
15 „	1·351	·637	·260	·050
22 „	2·093	1·008	·210	·100

Average purification effected = 43·1 per cent.

The purification effected by this filter was less than that attained by any of the remainder. The clarification was also less than in the case of the pea ballast and proprietary filters, being exactly the same as effected by the coke breeze. This was undoubtedly owing to the extreme looseness and porosity of the materials. The filtrate was free from putrefactive odour, remaining sweet for many months in either stoppered or open bottles. No work of any kind was done on the filter after the experiment started beyond filling up a few holes that formed during the first week's running.

Filter No. 2. Pea Ballast.—This filter, of precisely the same form and dimensions as the last, was filled with Lowestoft shingle, of pea size. The clarification effected in the filtrate was 75 per cent. more than in the case of the burnt ballast. The purification was also greater, the reduction of oxidisable organic matter amounting to 52·5 per cent. The following table shows the several analyses made:—

Date, 1892.	Oxygen absorbed in 4 hours.		Albuminoid ammonia.	
	Crude effluent.	Filtrate.	Crude effluent.	Filtrate.
14 June	3·311	1·631	—	—
15 „	2·154	1·615	—	—
17 „	1·909	1·518	—	—
21 „	2·255	1·011	·250	·260
24 „	2·205	·826	·230	·090
29 „	·890	·509	·150	·130
7 July	1·533	·805	·220	·090
8 „	1·330	·770	·200	·130
11 „	1·624	·812	·250	·250
13 „	1·230	·371	·380	·230
15 „	1·610	·875	·330	·140
18 „	2·611	·448	·270	·090
20 „	1·260	·770	·170	·120
22 „	2·415	1·246	·350	·130
10 August	2·198	·488	·230	·150
15 „	1·351	·399	·260	·060
22 „	2·093	·868	·210	·120

Average purification effected = 52·3 per cent.

In the case of this filter also no renovation or alteration was needed.

Filter No. 3. Coke Breeze.—The filter was filled with coke breeze to a depth of 4ft., and 3in. of gravel was placed on the top to prevent the coke from floating. As far as clarification is concerned, this filter ranked just even with the burnt ballast; but the purification effected was higher than in the case of any of the other materials, the reduction of the oxidisable organic matter in solution amounting to 62·2 per cent. No renewal of the material was required, the only work done being the filling up of a few subsidence holes. The results of the various analyses made are set forth in the following table:—

Date, 1892.	Oxygen absorbed in 4 hours.		Albuminoid ammonia.	
	Crude effluent.	Filtrate.	Crude effluent.	Filtrate.
14 June	3·311	1·442	·430	·120
15 „	2·154	1·346	—	—
17 „	1·909	1·431	·270	·120
21 „	2·255	·233	·250	·070
24 „	2·205	·352	·230	·080
29 „	·890	·381	·150	·100
7 July	1·533	·539	·220	·040
8 „	1·330	1·050	·200	·070
11 „	1·624	·609	·250	·110
13 „	1·230	·294	·380	·160
15 „	1·610	·511	·330	·100
18 „	2·611	·448	·270	·140
20 „	1·260	·560	·170	·140
22 „	2·415	1·183	·350	·110
10 August	2·198	·658	·230	·140
15 „	1·351	·322	·260	·040
22 „	2·093	·728	·210	·110

Average purification effected = 62·2 per cent.

Filter No. 4. Sand.—This filter, having an area of 16 square yards, or 1-300th of an acre, was filled with gravel, walnut size 5 inches, bean size 2½ inches, pea size 1½ inches, and sand 10 inches, taken in order from below upwards. It formed part of the compound proprietary filter. The rate at which effluent was passed through was one-half more per square yard than in the case of the other filters, the sand filtration being a preliminary to the treatment by the proprietary article, and the areas of the two portions being together equal to one of the remaining filters, already described.

The clarification effected was much greater than in the case of Nos. 1, 2 and 3, but the purification, measured by the reduction in the amount of oxidisable matter in solution, was considerably less than in the case of the coke breeze, somewhat less than by the pea ballast, and only very slightly better than by burnt clay. On two occa-

sions the filtrate became slightly putrid, the results thereby differing from those obtained from any other filtering material employed. Doubtless this tendency to become putrid was to a great extent due to the deficient aëration of the interior of the filter, in consequence of the capillary attraction of the finer particles of sand holding the water, and thus choking the pores when the filter was emptied. This filter had to be repeatedly raked and cleared, whilst 2½ inches of sand were removed and replaced by new on the 11th of July.

The following are the results of the analyses made :—

Date 1892.	Oxygen Absorbed in 4 hours.		Albuminoid Ammonia.	
	Crude Effluent.	Filtrate.	Crude Effluent.	Filtrate.
21 June	2·255	1·555	·250	·200
24 „	2·205	·735	·230	·050
29 „	·890	·750	·150	·100
7 July	1·533	1·267	·220	·080
8 „	1·330	1·050	·200	—
11 „	1·624	1·218	·250	·190
13 „	1·230	1·106	·380	·240
15 „	1·161	·875	·330	·110
18 „	2·611	·378	·270	·150
20 „	1·260	·700	·170	·080
22 „	2·415	1·442	·350	·150
10 August	2·198	·980	·230	·110
15 „	1·351	·798	·260	·140
22 „	2·093	1·155	·210	·120

Average purification effected = 46·6 per cent.

No. 5. Proprietary Filter.—This filter contained an area of 8 square yards, and was filled with 3 inches of gravel walnut size, 2 inches gravel bean size, 1½ inches gravel pea size, 1 in. sand, and 12 inches of the proprietary material ; taken in order from below upwards.

The effluent which it received had already passed through filter No. 4 (sand), and had thus been greatly clarified, whilst the dissolved impurity had been removed to the extent of 46·6 per cent. The rate of filtration was three times that of the other filters, so as to bring up the rate of the combined filter to an equality with the rest. The filter was supplied with perforated pipes, leading to the surface, for aëration. In general appearance the filtrate from this compound filter was slightly superior to all the others, the clarification effected being a little more than in the case of the sand forming the first portion. The purification effected by this process of double filtration amounted to 61·6 per cent., a figure practically the same as was obtained by the use of coke breeze. None of the filtrates showed any signs of putrescence when kept for lengthened periods in either open or closed bottles.

This compound filter was erected by the proprietors of the special filtering material, and worked in accordance with their wishes. It will be observed that sand and gravel played a very large part in the process. The following are the results of the analyses made :—

Date 1892.	Oxygen Absorbed in 4 hours.		Albuminoid Ammonia.	
	Crude Effluent.	Filtrate.	Crude Effluent.	Filtrate.
14 June	3·311	·679	·430	·170
15 „	2·154	·808	·270	·220
17 „	1·909	·955	·270	·160
21 „	2·255	·700	·250	·150
24 „	2·205	1·841	·230	·090
29 „	·890	·953	·150	·090
7 July	1·533	·539	·220	·110
8 „	1·330	·910	—	—
11 „	1·624	·609	·250	·090
13 „	1·230	·231	·380	·090
15 „	1·610	·371	·330	·100
18 „	2·611	·749	·270	·110
20 „	1·260	·350	·170	·070
22 „	2·415	1·246	·350	·050
10 August	2·198	·406	·230	·040
15 „	1·351	·322	·260	·100
22 „	2·093	·581	·210	·060

Average purification effected - 61·6 per cent.

Summary of Experiments with Small Filters and Various Filtering Materials.

The average rate of working, including rest periods, was 411,000 gallons per acre in 24 hours. The mechanical cleansing, or clarification, is shown as follows, the figures representing units of depth required to obscure a standard mark :—

Burnt ballast	1
Coke breeze	1
Pea ballast	1¾
Sand (1st portion of compound filter)	2½
Proprietary article (2nd portion of compound filter after sand)	2½

The following table shows the extent of the purification effected, as indicated by the reduction in oxidisable organic matter in solution :—

Burnt ballast	43·3 per cent.
Sand (1st portion of compound filter)	46·6 „
Pea ballast	52·3 „
Proprietary article and sand combined	61·6 „
Coke breeze	62·2 „

From the results obtained it appeared that a considerable amount of purification could be effected by any filtering material, the desiderata evidently being porosity and consequent power of re-absorbing atmospheric oxygen. For foul waters sand proved too fine ; whilst the burnt ballast used was too coarse. Coke breeze seemed to unite the necessary qualifications, and as it is also a cheap material it was selected for the further trials on a large scale. There can be little doubt, however, that the question of cost of material should be allowed to decide what should be used for a filter in any given place, since burnt ballast or gravel may be made much more efficient by using a greater depth of more finely granulated material combined with a slower rate. The proprietary filter excelled the coke breeze only in appearance, the actual purification not being quite so much, while the cost is prohibitory.

In the course of the above experiments, numerous gelatin plate cultivations were made, to ascertain the effect of filtration upon the number of micro-organisms present. The number in the tank effluent before filtration and in the filtrates was found to vary very considerably, those in the filtrate generally being present in larger numbers ; but it soon became apparent that the presence of comparatively few or more microbes afforded no indication of the degree of purification effected, the main point being that the presence of a large number of organisms was evidence of the activity of the process of splitting up the organic compounds in the sewage matters passing through the filters. A considerable reduction of organisms might have been effected by the use of a finer grained material and slower filtration, but the object held in view during the experiments was the attainment of the highest degree of speed consistent with such purification as would remove all objectionable characters, such as odour, colour, and liability to putrefaction.

Series No. 2.

In the second series of experiments a filter was constructed covering exactly one acre of land. The ground was levelled and embanked where necessary, and perforated drains laid, meeting in a common trunk for discharge. The filtering material consisted of 3 feet of coke breeze, covered with 3 inches of gravel.

(*a*) In the first part of the series under notice the special object of the experiments was rather the ascertaining of the rate at which it was possible to pass effluent through the filter, and not the manner of producing the best results. The filter, however, speedily became clogged with sludge, and after the sixth week all the filtrates were putrid. The daily quantity that could be passed fell rapidly until at the end of twelve weeks the filter was quite useless, being putrid throughout. Valuable information was thus gained, for it was shown that rest and aeration were vital, and also that in order to obtain the best work from a filter, the quantity poured on it must increase very gradually, so as to permit of the proper biological condition being reached. The rate of working varied from close on one million to a quarter of a million gallons per diem. The filling was during several weeks continued until the water stood 6 inches above the surface, when the filter was emptied this portion ran through without having time for purification, and this fact doubtless aided largely in reducing the efficiency of the filter during this set of experiments.

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During this period the following analytical results were obtained:—

Date 1893.	Oxygen Absorbed in 4 hours.		Albuminoid Ammonia.		Nitrogen as Nitrates.		Purification effected on Oxygen absorbed. Per cent.
	Effluent.	Filtrate.	Effluent.	Filtrate.	Effluent.	Filtrate.	
28 September to 6 October	3·631	2·128	—	—	·000	·083	41
9 October to 13 October	2·884	·509	—	—	·029	·215	82
16 „ to 20 „	3·295	·502	—	—	·029	·117	85
23 „ to 30 „	3·915	1·447	—	—	·103	·021	63
30 „ to 6 November	4·420	1·546	—	—	·000	·000	65
6 November to 13 „	4·404	1·285	·394	·110	·283	·203	71
13 „ to 20 „	4·122	1·125	·368	·097	·299	·317	73
20 „ to 27 „	4·336	1·203	·403	·091	·304	·241	72
27 „ to 4 December	4·832	1·135	·457	·119	·180	·175	77
4 December to 8 „	4·745	1·070	·435	·109	·077	·080	77
11 „ to 18 „	3·821	·979	·401	·092	·021	·130	76
19 „ to 23 „	4·877	1·387	·393	·191	·000	·000	71·6

(*b*) The first series of experiments on biological lines conducted with the same filter as the preceding was then commenced. The surface was raked, and the bed was allowed to rest during three and a half months. For fully three months of that time a putrid odour was observable when the filter was disturbed, but this gradually disappeared, and during the last fortnight the coke breeze was perfectly sweet. From that time the filter was kept practically constantly at work for nearly a year, the only rest of any length being from the 17th of November, 1894, to the 2nd of January, 1895, when alterations in the arrangements were made to admit of more rapid emptying.

The process adopted was to begin with small quantities, the filter being merely filled and emptied twice daily, with a view to getting it into the necessary biological condition. This was commenced on 2nd April, 1894, and continued for a few weeks, the purification effected gradually rising. The quantity of effluent passed was about 500,000 gallons per diem, and the purification between 70 and 80 per cent. The highest state of efficiency was reached on the 3rd May, or after a full month's working. The purification reached 83 per cent., and fish placed in the filtrate were kept alive for many weeks. In fact, fish (minnows and sticklebacks) came up the ditch by which the filter was emptied to the very mouth of the outlet.

The following are the weekly averages of the analytical results:—

1894. Week ending	Oxygen absorbed from Permanganate in 4 hours.		Albuminoid Ammonia.		Nitrogen as Nitrates.		Purification on Oxygen absorbed.
	Effluent.	Filtrate.	Effluent.	Filtrate.	Effluent.	Filtrate.	Per cent.
7 April	4·634	1·428	·440	·159	·455	·721	69·1
14 „	4·627	1·027	·521	·128	·095	·212	77·8
21 „	4·283	·954	·485	·105	·095	·104	77·8
28 „	3·977	·800	·507	·107	·471	·745	79·9
5 May	4·300	·722	·502	·096	·0636	·106	83·2
12 „	4·105	·844	·394	·090	·0308	·1145	79·4
19 „	3·879	·814	·308	·055	·0000	·0413	79·0
26 „	3·877	·657	·303	·059	·0000	·1310	83·1
2 June	4·033	·703	·401	·086	·0000	·1041	82·6
9 „	3·247	·611	·303	·069	·0700	·0994	81·2

(*c*) Alterations were then made in the arrangements for filling, the feeding trough being doubled. The daily quantity was increased to over 600,000 gallons, the analytical results continuing to be highly satisfactory, as shown by the following weekly averages:—

1894. Week ending	Oxygen absorbed from Permanganate in 4 hours.		Albuminoid Ammonia.		Nitrogen as Nitrates.		Purification on Oxygen absorbed.
	Effluent.	Filtrate.	Effluent.	Filtrate.	Effluent.	Filtrate.	Per cent.
3 August	3·195	·685	·365	·094	·0350	·2245	78·6
10 „	3·217	·661	·329	·081	Not estimated		79·5
17 „	3·345	·661	·332	·079	ditto		80·2
24 „	3·132	·661	·271	·057	ditto		78·9
31 „	3·504	·819	·296	·077	ditto		76·6
7 September	4·495	·785	·390	·082	·0350	·0876	82·5
14 „	3·530	·712	·356	·087	·0000	·1341	79·8
21 „	4·080	·767	·419	·136	·0700	·0632	81·2
28 „	3·540	·745	·521	·103	·0000	·1344	79·0
5 October	4·006	·808	·553	·244	·0000	·1690	80·0
12 „	3·648	·828	·519	·243	·0350	·0989	77·3
19 „	4·242	·781	·439	·117	·0000	·0675	81·6
26 „	3·964	·740	·460	·132	·0000	·0678	81·3
2 November	2·497	·540	·292	·080	·0708	·3063	78·4
9 „	3·726	·762	·406	·089	·0000	·2020	79·5

(*d*) Towards the end of 1894 the emptying arrangements were supplemented by a pump, and later the resting time was shortened, until finally the filter passed 1½ million gallons daily for six days, resting empty from 10 p.m. on Saturdays until 6 a.m. on Mondays. The method adopted was to fill the filter to just level with the surface as quickly as possible; allow it to remain standing full for one hour, and then draw off with the least possible delay. Working in this way the filter passed an average of one million gallons a day, including all times of rest, during

a period of eight weeks, the filtrates being clean and sweet and the purification effected 78 per cent. Nitrification proceeded satisfactorily, and the filter was apparently capable of continuing for an indefinite time.

A point of the greatest importance is the fact that the filter was able to do its work satisfactorily during the exceptionally severe weather in January and February, 1895. A thin coat of ice was formed on the surface, but the filtration proceeded without intermission, the only noticeable change being the decreased production of nitric acid. 19 Oct. 1898.

The following are the weekly averages of analytical results—

Week ending	Oxygen absorbed from Permanganate in 4 hours.		Albuminoid Ammonia.		Nitrogen as Nitrates.		Purification on Oxygen absorbed.
	Effluent.	Filtrate.	Effluent.	Filtrate.	Effluent.	Filtrate.	Per cent.
1894.							
16 November	2·412	·491	·259	·079	·5648	·8618	79·6
1895.							
4 January	5·240	1·190	·447	·150	·6371	1·6386	77·3
12 „	4·045	1·103	·434	·162	·3765	·8973	73·0
19 „	4·202	·817	·441	·112	·3830	·9805	81·0
26 „	3·762	·742	·352	·085	·7826	1·1130	80·3
2 February	3·695	·801	·362	·098	·3681	·6196	78·3
9 „	4·016	·971	- - Not estimated - -		·3830	·4549	75·8
16 „	4·281	·891	- - - ditto - - -		·2547	·3438	79·2
23 „	4·967	1·047	- - - ditto - - -		·1122	·0804	78·9
2 March	4·524	1·293	- - - ditto - - -		·0937	·0000	71·4

(*e*) After the filter had been successfully dealing with one million gallons daily for about eight weeks a large quantity of sludge, amounting to at least ten tons, was run upon it accidentally. This occurred during the week ending 23rd February. The result was an immediate falling off in the quality of the filtrate; a putrescent odour was observed; and finally the filter had to be thrown out of work. Remarkable evidence of the recuperative power of the coke breeze was however obtained, as after 20 days' rest it was quite sweet again, nothing objectionable being observed on digging down to a depth of about 2 feet. The coke had only the odour of ordinary earth when moist, and on being burnt gave no objectionable smell.

On resuming work, 28 days after resting, the following satisfactory results were obtained:—

Date. 1895.	Oxygen absorbed from Permanganate in 4 hours.		Albuminoid Ammonia.		Nitrogen as Nitrates.		Purification on Oxygen absorbed.
	Effluent.	Filtrate.	Effluent.	Filtrate.	Effluent.	Filtrate.	Per cent.
8 April	3·048	·810	·370	·096	·0000	1·0166	73·5
9 „	4·095	·810	·418	·124	·0000	·6350	80·2
10 „	2·571	·905	·358	·104	·0000	·6584	64·8
16 „	3·238	·705	·401	·123	·0000	·7559	78·3
17 „	3·429	·762	·261	·080	·4941	·9438	77·8
18 „	4·476	·952	·343	·104	·3335	·8161	78·8
19 „	4·381	1·048	·385	·080	·0000	·7008	76·1
20 „	2·857	·762	·348	·104	·3171	·6336	73·4

From this time until the end of September in the same year the filter was kept continuously at work (except during one week in August) on the same system, viz., alternate filling, resting full, and emptying, with 24 hours entire rest each week. The results are shown in the following table; the figures given are weekly averages of daily analyses, the samples on which the latter were made being themselves averages of quarter-hour samples from each filling and emptying.

Date. 1895. Week ending	Quantity of Effluent passed Daily per Acre. Average of 7 days.	Oxygen absorbed in 4 hours. Average of 7 days.		Purification, per cent.	Remarks.
		Effluent.	Filtrate.		
4 May	1,049,776	3·592	·753	79·0	
11 „	1,050,878	3·576	·861	75·9	
18 „	1,128,138	3·867	·865	77·6	
25 „	1,076,939	3·657	·862	76·4	
1 June	932,171	4·009	1·013	74·7	
8 „	725,718	3·399	·841	75·3	
15 „	980,408	3·247	·872	73·1	
22 „	925,621	3·496	·698	80·0	
29 „	779,282	3·441	·566	83·6	
6 July	959,512	3·576	·614	82·8	
13 „	1,049,042	3·282	·572	82·6	
20 „	956,825	3·219	·531	83·5	
27 „	964,416	2·852	·490	82·8	
3 August	839,472	3·359	·538	83·8	
10 „	—	—	—	—	Filter not used.
17 „	966,881	2·810	·450	87·6	
24 „	959,341	2·928	·485	83·5	
31 „	966,042	2·670	·467	82·5	
7 September	971,502	2·683	·503	81·3	
14 „	1,013,071	2·573	·470	81·8	
21 „	1,014,667	2·746	·461	83·2	
28 „	1,013,071	2·889	·491	83·0	

19 Oct. 1893.

The experiments taken as a whole show that sewage, especially if previously clarified by precipitation, may be purified to any desired degree, the actual amount of purification depending upon (1) the length of time during which the effluent is allowed to remain in contact with the filter, and (2) the length of time allowed for aeration. If a reduction of 75 per cent. in the oxidisable organic matters in solution be considered as sufficient, the quantity that can be treated per diem on one acre of coke breeze is one million gallons, which give a required area for the treatment of the whole of the metropolitan sewage—taken at 180 million gallons—of 180 acres only. This rate is probably the highest that can be worked under all conditions of seasons.

If, however, only the effluents from the strong day sewage were submitted to filtration, as those from the weak night sewage obtained by precipitation after chemical treatment are sufficiently satisfactory, the area required would be proportionately reduced, viz., to about 120 acres.

Experiments with Sewage Collected on the "Separate" System, Excluding Rainfall.

By the courtesy of the Sutton (Surrey) Urban District Council I am enabled to append the following statement of results obtained by similar treatment of the sewage as carried out at the sewage works of that Council. The trials in question were made during the period of office of the late Sutton Local Board, of which authority I was at that time a member, and therefore am able to speak of the results from personal experience. The works were under the direction of Mr. A. D. Greatorex, Assoc. M.I.C.E., surveyor to the Board.

The filters employed are seven in number, as follows—

	Area.
2 proprietary, 35 ft. by 20 ft.	700 sq. ft. each.
2 coke breeze " "	700 "
2 sand " "	700 "
	4,200
1 burnt ballast $\left\{\begin{matrix}142\\120\end{matrix}\right\}$ ft. by 34 ft.	4,454 "
Total area	8,654 "

The filters are constructed as follows—

Proprietary.

Top	6½	in., medium sand.
"	3	" pea gravel.
"	10½	" proprietary article mixed with sand.
"	5	" extra coarse sand.
"	4	" pea gravel.
Bottom	5	" coarse shingle round the pipes.

Coke Breeze.

Top	8	" medium sand.
"	12	" coke breeze.
"	5	" extra coarse sand.
"	4	" pea gravel.
Bottom	5	" coarse shingle.

Sand.

Top	8	" medium sand.
"	12	" " "
"	5	" extra coarse sand.
"	4	" pea gravel.
Bottom	5	" coarse shingle.

Burnt Ballast.

Top	4	" soil.
"	6	" fine ashes.
Bottom	18	" burnt ballast.

120,000 gallons of effluent water are passed through the filters per day, working nine hours. The six small filters are worked one day and the large the next day, thus allowing alternate days of rest; the six filters have been at work nearly two years and the large one three months, with the exception of the bad days in the winter.

The percentage purification of the oxidizable organic matters effected is shown in the following table, which is prepared from analyses made by Dr. Jacob, medical officer of health for the Sutton district—

Date. 1894.	Proprietary filter.	Coke breeze filter.	Sand filter.
May 2nd	36·4	47·6	31·0
July 13th	51·5	41·0	32·2
"	—	50·0	—
"	—	53·0	—
Oct. 16th	61·0	51·0	30·0
"	54·0	48·0	24·0
Nov. 24th	53·3	14·9	50·0
"	44·2	26·5	51·6
Average	50·1	41·5	36·5

On the 24th April, 1895, Mr. Greatorex kindly collected for me a series of samples of crude sewage, precipitation effluent and filtrates, the samples being averages of ten hours' working. These were analysed in the Council's laboratory, and yielded the following results—

24th April, 1894.	Sewage, including suspended matters.	Sewage, excluding suspended matters.	Effluent before filtration.	Burnt ballast filter.	Sand filter.		Proprietary filter.		Coke breeze filter.	
					No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
Oxygen absorbed	8·98	4·29	2·292	2·54	1·13	1·08	1·22	0·85	0·85	0·66
Purification per cent. on unfiltered effluent.	—	—	·0	13·0	61·3	63·0	58·3	70·9	70·9	77·4
					62·1		64·6		74·1	

From the first table of the results obtained at Sutton, it would appear that the proprietary filter gave the best results; but this was caused by the lower rate at which this filter worked, as in many instances, in consequence of the finer grain of material and frequent choking, the quantity passing through the bed was far less than that passed by the remaining filters. In the case of the experiments conducted at Barking Creek the rates of flow were maintained at equal speed. In the second table of Sutton results, however, the coke breeze filter excelled all the others, the proprietary and sand filters being very close together.

From the above results it would appear that the burnt ballast filter has been overworked and requires a short period of rest, as a former result was exceedingly satisfactory.

In his report of the 18th July, 1894, Dr. Jacob stated that the effluents from the various filters were quite fit

to be discharged into the brook without further treatment.

Conclusions.

The action of a filter is twofold:—(1) It separates mechanically all gross particles of suspended matter and renders the effluent clear and bright. (2) It effects the oxidation of organic matters, both those in suspension and those in solution, through the agency of living organisms. It is the preliminary establishment and subsequent cultivation of these organisms which is to be aimed at in the scientific process of purification by filtration.

The ordinary putrefactive and other similar organisms commence the work by breaking down the organic compounds and converting them to less complex forms, principally water, carbonic acid and ammonia; the nitrifying organism then acts upon the ammonia, the nitrogen being converted into nitric acid. For this process to go on, three conditions are essential. Firstly, the organisms must be supplied with plenty of air; secondly, there must be present a base, such as lime, with which the nitric acid can combine; and thirdly, the biological action must take place in the dark, *i.e.*, in the body of the filter and not in the water exposed to the light above the filtering material. Filtration on biological lines of sewage or other foul water containing in solution but little free oxygen and a large quantity of oxidizable organic matter therefore means:—

(1.) That the filter, by cautious increments in the quantity of effluent, which in itself contains the necessary organisms, must be gradually brought to a state of high efficiency. This condition will be shown by the existence in the filtrate of a constantly increasing proportion of nitric acid.

(2.) That the contact of the micro-organisms with the effluent to be purified must be effected by leaving such effluent at rest in the filter for a greater or less time according to the degree of purification required, the process being analogous to that of fermentation. The system employed in many places is to run the water straight through the filter and thus allow insufficient time for the work, with the result that the filtrate is soon in an unsatisfactory condition.

(3.) That after each quantity of effluent has been dealt with the micro-organisms must be supplied with air, which is readily effected by emptying the filter from below, whereby air is drawn into the interstices. The filter must stand empty for an hour or more previous to another filling and a longer period of aeration, say 24 hours, must be allowed every seven or eight days.

The life of a coke breeze filter worked in this manner is practically without a limit.

From the general results obtained by these several trials under various actual working conditions it is apparent that there is no difficulty in obtaining any desired degree of purification by means of a system of filtration conducted on biological principles. If a higher degree of purity be required than that indicated by the foregoing, it can be obtained by an augmentation of the filtering appliances at a comparatively small cost, as, where clay is obtainable, the method of construction employed in making the new burnt ballast filter bed at Sutton may be adopted, viz., by simply digging out the clay so as to form a pit about 3 feet deep, and filling it up with the same clay after burning, and thus a cheap and efficient filter bed is obtained, the cost of the large filter bed at Sutton, having an area of 4,454 square feet, or rather more than one tenth of an acre, being less than £100, including all charges.

By such a system the necessity for costly farms is entirely obviated. The results are completely under control, and the filters can be arranged to suit all requirements it is possible to contemplate.

W. J. Dibdin,
Chemist.

40, Craven Street, W.C.,
October, 1895.

SCHEDULE 2. 19 Oct. 1898.

THE BACTERIAL TREATMENT OF SEWAGE CONTAINING MANUFACTURING REFUSE.

(Reprinted from the Journal of the Society of Chemical Industry, 30th April, 1898. No. 4, Vol. XVII.)

By W. J. Dibdin, F.I.C., F.C.S., and G. Thudichum, F.C.S.

Some three years since one of us presented to this Society the results of our experience with regard to the bacterial treatment of the sewage effluent at the Northern Outfall works at Barking Creek, carried out for the main Drainage Committee of the London County Council. The outcome of these experiments was the clear demonstration of the fact that the (principally) dissolved matters remaining in the sewage after treatment with lime and protosulphate of iron could be practically rendered innocuous by subjecting them to the attack of bacteria under suitable conditions; and these conditions were to a great extent ascertained and set forth in the communication above alluded to.

The system then adopted and applied to the purification of effluent from which the suspended solids had been removed by precipitation has since been shown to be capable of extension to a degree at that time unsuspected, since by the bacterial action alone the whole of the solid matters in the crude sewage may be destroyed and the effluent water rendered innocuous and unobjectionable. This has been shown to be the case by long-continued working at Sutton, Surrey, where experimental purification of the sewage as it arrives on the works, bacterial agencies alone being employed, has been in successful operation for some 18 months. These experiments have already been published, and need not, therefore, be now further referred to beyond a statement as to the general result of the work, which may be summed up in the table on page 3.

It having been thus shown that the bacteriological action is fully equal to the task of purifying domestic sewage under ordinary conditions, it remained to be ascertained whether sewage containing relatively large quantities of refuse from various manufactories could be treated on the same lines with equal success. As we have had ample opportunity of testing this important point, we venture to submit for the information and criticism of the members of the Society the outcome of the work done in this direction.

We would first point out that London sewage, upon which the whole of our earlier experiments were carried out, contains very large quantities of manufacturing refuse of all kinds. It has been frequently stated that up to quite recently we had dealt with domestic sewage only, and that when the method was tried in manufacturing towns it would probably fail There is, of course, in the sewage of London no such preponderance of any particular kind of trade refuse as is found in some other towns, as, for instance, the iron pickle liquor in Leeds and West Bromwich, the refuse from the leather dressers at Yeovil, or the dye liquors in some of the northern towns; but the members of this Society are probably better informed than the general public as to both the quantity and the nature of the various trade effluents which are passed into the metropolitan sewers. We may fairly say that, whilst the Sutton experiments were made with a purely domestic, although very strong, sewage, the Barking Creek results were obtained from a sewage containing all manner of trade refuse, but with no special preponderance of any one kind.

Turning now to places in the case of which the special pollutions are strongly emphasised, it will be well to set out the more important of the various descriptions of refuse which have been dealt with, and then to discuss the results of the treatment of the sewage into which these are discharged in quantities to make their presence individually evident.

The special trade effluents examined are:—Tan liquor, brewery waste, distillery waste, leather dressers, acid iron pickle liquor, milk washings, gas liquor, soap works, paper mills, margarine factories.

Experiments at Leeds.

As a type of sewage highly charged with refuse from various manufactories, and in which one special component is strongly marked, that of Leeds may be considered with advantage. By the courtesy of Colonel Harding, the Chairman of the Streets, &c., Committee of the Cor-

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poration of Leeds, we are enabled to place before you the results of the experiments which have been carried out at the Knostrop works at Leeds since the first of October last.

Average during Month.	Crude Sewage.			Coarse Bed.			Fine Bed.		
	Oxygen absorbed in 4 Hours.	Albuminoid Ammonia.	Nitrogen as Nitrites and Nitrates.	O 4 Hours.	NH_3 Alb.	N as Nitrites, &c.	O 4 Hours.	NH_3 Alb.	N as Nitrites, &c.
	Grains per Gallon.								
November 1896 -	4·245	...	...	1·795	...	...	0·858	...	...
December „ -	6·219	...	...	1·782	...	...	0·759	...	...
January 1897 -	5·223	...	...	1·924	...	...	0·634	...	...
February „ - -	4·464	0·278	Trace	1·378	0·189	0·566	0·542	0·147	1·649
March „ - -	5·044	1·108	Nil	2·057	0·381	0·740	0·614	0·173	1·313
April „ - -	3·111	0·893	Nil	0·789	0·185	0·936	0·434	0·119	1·549
May „ - -	3·873	0·706	Nil	1·949	0·486	0·207	0·759	0·222	0·192
July „ - -	2·757	...	Trace	1·849	...	0·148	1·185	...	0·353
September„ - -	1·295	0·154	Nil	0·350	0·067	0·410	0·210	0·037	0·742
January 1898 -	3·00	0·78	Nil	0·670	0·120	0·600	0·360	0·080	1·530
March „ - -	2·58	0·25	Nil	0·750	0·120	0·098	0·320	0·040	2·250

The bacteria beds employed are filled with coke in the manner elsewhere suggested, and consist of a coarse bed followed by a fine one. The depth of the first one is 4ft. 6in., and that of the second 5ft. The quantity of sewage dealt with is about 200,000 gallons daily.

During the first three months the sewage was put on to the coarse bed directly, without any straining other than that which it received by passing through a screen having a 1¼in. mesh before arriving at the pumps. This resulted in a quantity of fibrous matter, largely composed of wool refuse, accumulating upon the surface of the bed; but this defect has now been remedied, and so far there appears to be no reason to anticipate any renewal of the trouble thus caused, which, however, did not affect the satisfactory character of the final effluent, the chief symptom being a too great reduction in the original water capacity of the bed.

During the first three months the beds were used twice a day, with the result that they were gradually brought into thoroughly good working condition, as is shown by the following table of averages of the daily analyses which were made:—

Crude Sewage.		Coarse Bed Effluent.		Fine Bed Effluent.	
Oxygen absorbed, 4 hours.	Albuminoid Ammonia.	Oxygen absorbed, 4 hours.	Albuminoid Ammonia.	Oxygen absorbed, 4 hours.	Albuminoid Ammonia.
3·91	0·372	2·42	0·212	0·84	0·115

It was noticed that nitrification was only developed to any extent at about the seventh week, and that it never attained the proportions found in dealing with the purely domestic sewage of Sutton. This is, of course, in part due to the Leeds sewage being much poorer in nitrogen, and partly also to the very large quantities of iron liquor frequently present. It was observed that whenever the incoming sewage was acid, it retained that reaction through both stages of the treatment. So powerful, however, was the oxidizing action of the beds that not only was the organic matter acted upon, but the iron salts in solution, which in the crude sewage were ferrous, were in many instances found in the final effluent to be completely changed into the ferric state. In the majority of the samples the iron separated out after a time and settled as ferric oxide in the bottom of the vessel, leaving an absolutely clear and brilliant effluent.

When the beds were filled three times per diem the results obtained were to all intents and purposes as good as before, but the trouble mentioned above, viz., the collection of fibrous matter on the coarse bed, somewhat delayed the experiments in order to arrange for the fitting of suitable screens.

The following shows the average of the analyses made whilst the beds were thus working at the increased rate:—

Coarse Bed Effluent.		Fine Bed Effluent.	
Oxygen absorbed, 4 hours.	Albuminoid Ammonia.	Oxygen absorbed, 4 hours.	Albuminoid Ammonia.
1·31	0·15	0·53	0·066

The general character of the effluents is all that can be desired. They are (after the separation of the iron) bright and clear, they are practically without smell, a very slight earthy odour being occasionally noticeable; they are absolutely non-putrescible, and fish can live and thrive in them in the state in which they issue from the beds directly, as has been demonstrated by actual trial, extending over three months, in the course of the experiments under notice. It is thus evident that if such an effluent were allowed to flow into a river even of relatively very small volume there would be no cause for alarm as to its effect upon fish life, which may be taken as a crucial point in regard to the purification of sewage entering streams which are not afterwards used for the purpose of supplying potable water.

Having regard to the facts that these results have been obtained during the winter months we may reasonably hope that as the warm weather sets in the work done by the bacteria beds will be even more effectual.

The particular trade effluents entering the Leeds sewage are those derived from tanneries, galvanising works, copper works (wet process), with large quantities of shoddy waste.

Experiments with Maidstone Sewage.

The sewage of Maidstone contains large quantities of brewery and tannery refuse, and is organically twice as strong as that of Leeds, the albuminoid ammonia averaging 0·64 grains per gallon, as against 0·37 grains in the case of the last-mentioned towns. So far, experiments made with this sewage have been on a laboratory scale only, but satisfactory results have been obtained, as will be seen from a consideration of the average amount of

oxygen absorbed by the crude sewage and coarse and fine bed effluents respectively, as follows:—

——	Crude Sewage.	Coarse Bed.	Fine Bed.
Oxygen absorbed from permanganate in four hours, at 80° F. grains per gallon.	5·805	2·411	0·957

The albuminoid ammonia was, unfortunately, not estimated in all the effluents, but where done showed a reduction of 66·6 per cent. Since our almost invariable experience has been that work of this kind is always better when done on a large scale than when carried out in our small laboratory bacteria beds, we feel confident that the experiments about to be instituted at Maidstone will result in the production of a good effluent from a very foul sewage.

Experiments with West Bromwich Sewage.

In this case the chief trade effluent which enters the sewers is one derived from the galvanising works. This pickle liquor is of a nature similar to that mentioned in connection with the treatment of the Leeds sewage, and the experimental filters at West Bromwich have also worked out with great success. We might here state, however, that if an effluent be intended to be finally used on land, the iron must first be removed, either by previous lime precipitation or by aeration and settlement of the fine bed effluent in which it still remains in solution. This is a question of the utmost importance in the case of some towns, as, for example, Wolverhampton. Although the action of bacteria beds is not seriously impeded by the presence of the iron, we are nevertheless of opinion that it would be better to remove it by preliminary treatment, where such can be carried out at a reasonable cost.

Experiments with Yeovil Sewage.

The principal industry of Yeovil being the manufacture of glove leather, the chief trade refuse which enters the sewers comes from the yards of fellmongers and leather-dressers, and is of an especially obnoxious character. In addition to the organic impurities it contains arsenic, which is largely employed in the preparatory processes. 19 Oct. 1898.

In this case the system of treatment adopted has been the now well-known septic tank, in which a large proportion of the solid matters are first brought into solution by anaerobic agencies, and then oxidised by passing through fine bacteria beds. The results obtained are in all respects comparable with those given above.

In the cases which have so far been reviewed we have dealt only with sewage containing larger or smaller quantities of the specific effluents. It may be of interest to the members of the Society to instance some experiments made with bacteria beds upon some actual trade effluents in the condition in which they were discharged into the sewer. In each case the liquid was allowed to remain in a coarse bed for two hours, and following this in a fine bed for a similar period of time.

Special trials made on refuse liquor from tanneries, margarine works, galvanising works, gas liquor, milk washings, and yeast washings showed that in all cases observed a very considerable improvement was effected, excepting in the case of the gas liquor, which had to be somewhat diluted before being placed in the beds. The resultant effluents contained no suspended solids, and did not become putrid on keeping.

It will, of course, be understood that these samples are only given to show that the refuse liquors named are amenable to bacterial treatment; the effluent so produced must not in any way be taken as representative of what is required in the way of purification. It is, however, clear that if so much work can be done by passage through two beds, the purification can be extended by increasing the number of times of submission to microbial influences. In practice, concentrated chemical refuse liquors would have necessarily to receive special treatment in order to fit them for bacterial purification; excess of acid or alkali must be corrected; iron, if present in large quantities, removed; and so forth. The point which has been so far considered is as to the treatment of sewage containing manufacturing refuse; and, so far as our experience has gone, such sewages can be efficiently purified by the bacterial method equally with the domestic sewage from a purely residential neighbourhood.

19 Oct. 1898

TABLE OF RESULTS OF ANALYSES OF SAMPLES OF CRUDE

F.—AT SUTTON, SURREY.

(Quantities stated in Grains per Gallon.)

DATE OF COLLECTION.	CRUDE SEWAGE.									COARSE				
		Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Suspended Matters.		Dissolved Solids.			Ammonia.		Oxygen absorbed from Permanganate at 80° F.	
	Chlorine.	Free.	Albuminoid.	At once.	In 4 Hours.	Total.	Volatile.	Total.	Volatile.	Chlorine.	Free.	Albuminoid.	At once.	In 4 Hours.
21 November 1896	–	–	–	–	3·291	–	–	–	–	–	–	–	–	2·581
30 November 1896	–	–	–	–	5·200	–	–	–	–	–	–	–	–	1·060
8 December 1896	–	–	–	–	4·760	–	–	–	–	–	–	–	–	2·340
21 December 1896	–	–	–	–	7·677	–	–	–	–	–	–	–	–	1·225
4 January 1897	–	–	–	–	2·380	–	–	–	–	–	–	–	–	1·496
12 January 1897	–	–	–	–	5·578	–	–	–	–	–	–	–	–	1·904
18 January 1897	–	–	–	–	7·711	–	–	–	–	–	–	–	–	2·372
1 February 1897	–	–	–	–	6·590	–	–	–	–	–	–	–	–	1·720
8 February 1897	5·95	2·810	0·330	–	5·540	106·80	–	–	–	5·95	2·840	0·320	–	1·824
15 February 1897	6·30	2·700	0·258	–	1·911	15·06	–	–	–	6·30	1·350	0·118	–	0·588
22 February 1897	6·40	3·906	0·245	–	3·815	29·90	–	–	–	5·20	1·337	0·128	–	1·381
1 March 1897	8·05	7·770	0·602	–	4·248	28·14	–	–	–	8·05	3·860	0·304	–	2·222
8 March 1897	6·00	4·197	0·680	–	2·993	13·58	–	–	–	5·40	0·980	0·305	–	1·146
15 March 1897	11·10	13·600	1·260	–	4·941	29·62	–	–	–	5·60	1·275	0·325	–	1·860
22 March 1897	8·40	11·464	1·700	–	4·727	22·73	–	–	–	8·40	3·615	0·590	–	3·000
29 March 1897	23·10	51·700	1·300	–	8·812	–	–	–	–	–	–	–	–	–
5 April 1897	7·00	4·860	1·330	–	3·209	20·72	–	–	–	6·30	0·685	0·340	–	0·679
20 April 1897	9·00	6·210	0·750	–	2·495	25·55	–	–	–	7·70	0·780	0·175	–	0·720
26 April 1897	8·20	4·700	0·600	–	3·628	244·10	–	–	–	6·80	2·015	0·040	–	0·967
3 May 1897	8·00	5·250	0·570	–	3·480	51·85	–	–	–	7·50	1·455	0·225	–	1·044
10 May 1897	10·00	5·663	0·994	–	4·587	56·16	–	–	–	7·30	3·325	0·490	–	1·284
17 May 1897	9·20	3·264	0·590	–	2·999	54·25	–	–	–	8·50	3·981	0·850	–	2·727
24 May 1897	8·20	3,500	0·670	–	4·425	139·98	–	–	–	8·20	1·950	0·400	–	2·743
6 July 1897	6·50	–	–	–	2·288	27·50	15·4	53·6	20·0	7·60	–	–	–	1·698
26 July 1897	8·20	–	–	–	3·226	41·70	18·7	57·1	20·7	8·10	–	–	–	2·000
6 September 1897	7·60	10·150	0·154	–	1·295	37·50	29·9	56·4	12·2	7·20	3·487	0·067	–	0·350
17 January 1898	8·10	10·920	0·780	0·67	3·000	54·10	41·3	68·7	16·5	6·20	1·810	0·120	0·27	0·670
7 February 1898	8·30	9·240	0·500	0·89	2·770	38·30	25·3	54·8	13·4	7·10	2·600	0·180	0·19	0·940
17 February 1898	7·40	6·300	0·390	0·88	2·780	87·80	61·1	64·8	17·8	7·20	3·880	0·250	0·60	1·900
10 March 1898	4·40	3·990	0·250	0·65	2·580	54·80	37·4	53·1	12·0	6·00	2·180	0·120	0·09	0·750
16 March 1898	–	–	–	–	–	–	–	–	–	7·60	5·370	0·190	0·50	2·770
2 June 1898	6·50	6·120	0·260	0·98	2·580	102·4	72·9	54·4	19·6	6·80	4·140	0·110	0·11	1·260
30 June 1898	5·10	5·770	0·190	1·090	4·15	54·4	34·2	51·3	23·2	5·80	3·180	0·100	0·44	1·70
10 August 1898	5·60	4·930	0·270	0·670	3·42	42·0	27·7	57·2	17·0	6·70	6·300	0·200	0·16	1·24
25 August 1898	5·50	3·020	0·190	0·430	2·15	120·4	72·9	48·7	18·2	6·20	3·920	0·090	0·21	1·35
Average	–	8·001	0·620	–	3·992	57·7	–	–	–	–	2·767	0·251	–	1·543
Purification Per Cent.	–	–	–	–	–	–	–	–	–	–	65·5	59·6	–	61·4

SEWAGE AND EFFLUENTS FROM SEWAGE DISPOSAL WORKS.

WEEKLY AVERAGES.

(Quantities stated in Grains per Gallon.)

BED.						FINE BED.											
Nitrogen as		Suspended Matters.		Dissolved Solids.			Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as		Suspended Matters.		Dissolved Solids.	
Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.	Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.
–	–	–	–	–	–	–	–	–	–	0.316	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	1·400	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	0·939	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	0·580	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	0·748	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	0·476	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	0·677	–	–	–	–	–	–
–	0·450	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
0·630	0·0	3·20	–	–	–	5·60	0·140	0·270	–	0·675	0·053	2·714	0·80	–	–	–
0·159	0·112	3·45	–	–	–	5·95	0·060	0·081	–	0·294	0·022	0·505	0·86	–	–	–
0·084	0·539	3·73	–	–	–	6·20	0·165	0·090	–	0·657	0·049	1·606	2·37	–	–	–
0·021	0·0	2·83	–	–	–	5·95	0·135	0·072	–	0·457	0·035	1·495	Tr.	–	–	–
0·061	0·573	1·60	–	–	–	5·40	0·112	0·190	–	0·764	0·033	0·601	1·230	–	–	–
0·098	1·746	1·11	–	–	–	5·40	0·116	0·116	–	0·639	0·049	2·210	0·800	–	–	–
0·420	0·0	2·62	–	–	–	7·50	0·930	0·290	–	0·772	0·059	0·758	0·617	–	–	–
–	–	–	–	–	–	7·70	0·333	0·200	–	0·437	0·059	–	–	–	–	–
0·196	0·798	1·80	–	–	–	6·00	0·116	0·110	–	0·185	0·084	1·602	0·650	–	–	–
0·308	1·435	1·10	–	–	–	6·70	0·050	0·083	–	0·472	0·056	2·357	0·430	–	–	–
0·072	0·0	6·20	–	–	–	7·60	1·226	0·166	–	0·646	0·010	0·587	Tr.	–	–	–
0·113	0·245	4·44	–	–	–	8·00	2·233	0·016	–	0·870	0·113	0·187	1·600	–	–	–
0·051	0·0	1·97	–	–	–	8·40	3·752	0·252	–	1·009	0·010	0·0	0·430	–	–	–
–	0·180	4·53	–	–	–	7·70	0·300	0·500	–	0·363	0·026	0·154	0·370	–	–	–
0·103	0·136	0·86	–	–	–	8·50	0·400	0·120	–	0·796	0·041	0·227	Tr.	–	–	–
0·105	0·041	2·40	1·40	62·20	21·2	8·10	–	–	–	1·273	0·040	0·310	0·500	0·200	90·2	42·4
0·114	0·035	3·10	1·80	65·6	25·7	8·10	–	–	–	1·097	0·300	0·455	0·0	0·0	79·0	31·4
0·007	0·403	1·70	1·70	61·3	10·4	7·50	0·340	0·037	–	0·210	0·042	0·700	0·0	0·0	71·7	14·1
0·090	0·510	Tr.	Tr.	66·80	15·7	7·50	0·520	0·080	0·0	0·360	0·0	1·580	0·0	0·0	71·3	11·5
0·000	Tr.	Tr.	Tr.	58·80	12·4	7·50	0·140	0·040	0·05	0·330	0·0	2·800	0·0	0·0	69·7	11·3
0·000	Tr.	7·00	4·00	59·10	15·4	6·70	0·330	0·080	0·0	0·560	Tr.	2·680	0·0	0·0	69·7	11·3
Tr.	0·098	Tr.	Tr.	56·60	12·4	6·20	0·350	0·040	0·0	0·320	0·0	2·250	0·0	0·0	70·5	19·3
0·000	Tr.	14·80	10·00	68·10	10·0	7·00	0·750	0·006	0·0	0·590	0·110	1·950	0·0	0·0	Lost.	Lost.
0·000	Tr.	4·90	4·90	56·90	19·1	6·00	1·280	0·050	0·0	0·090	Tr.	2·030	0·0	0·0	56·7	19·0
0·000	0·059	6·00	1·90	50·70	16·9	5·70	1·220	0·050	0·0	0·760	0·070	1·635	0·0	0·0	62·2	18·4
0·000	0·112	3·40	2·70	61·00	12·3	6·30	1·600	0·070	0·0	0·620	0·049	2·771	0·0	0·0	65·0	9·5
0·000	0·000	Tr.	Tr.	55·20	18·6	6·40	1·050	0·070	0·0	0·810	0·056	1·984	0·0	0·0	61·6	21·0
–	–	3·16	–	–	–	–	0·705	0·123	–	0·641	–	–	0·395	–	–	–
–	–	94·5	–	–	–	–	91·2	80·2	–	84·0	–	–	99·3	–	–	–

19 Oct. 1898.

TABLE of Results of Analyses of Samples of Crude Sewage and

G.—AT KNOSTROP, LEEDS.

(Quantities stated in Grains per Gallon.)

DATE OF COLLECTION.	CRUDE SEWAGE.									COARSE				
		Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Suspended Matters.		Dissolved Solids.			Ammonia.		Oxygen absorbed from Permanganate at 80° F.	
	Chlorine.	Free.	Albuminoid.	At once.	In four hours.	Total.	Volatile.	Total.	Volatile.	Chlorine.	Free.	Albuminoid.	At once.	In four hours.
7 October 1897	12·1	3·12	0·25	0·93	2·567	18·8	10·5	55·2	19·0	11·6	2·66	0·16	0·76	1·920
14 October 1897	11·4	3·13	0·376	1·22	3·564	29·5	16·0	53·5	16·7	11·2	2·58	0·27	0·87	2·212
21 October 1897	9·5	2·27	0·315	1·42	3·680	32·7	19·2	55·4	17·6	9·1	2·14	0·249	0·94	2·670
28 October 1897	10·8	2·90	0·427	1·70	4·720	45·6	25·1	63·4	17·3	10·5	2·83	0·309	1·23	3·090
4 November 1897	10·7	3·54	0·470	2·33	4·86	48·8	35·9	69·3	24·5	10·4	2·77	0·252	1·48	2·74
11 November 1897	10·6	3·97	0·53	1·73	4·39	39·8	26·6	71·5	23·4	10·5	3·12	0·23	1·18	2·75
18 November 1897	9·6	3·62	0·35	1·45	3·90	37·1	21·3	57·8	15·1	9·2	2·88	0·16	0·75	2·29
25 November 1897	10·9	3·83	0·39	1·53	4·05	39·9	26·6	59·5	18·7	10·4	2·98	0·17	0·75	2·47
2 December 1897	10·7	2·30	0·25	1·11	3·25	45·5	32·0	60·9	13·7	10·9	2·13	0·13	0·43	1·60
18 December 1897	8·4	2·09	0·27	1·15	3·47	34·4	16·7	50·8	12·6	7·7	1·90	0·15	0·63	1·65
25 December 1897	–	–	–	–	–	–	–	–	–	7·6	1·32	0·18	0·47	1·57
31 December 1897	–	–	–	–	–	–	–	–	–	8·5	1·80	0·14	0·36	1·23
7 January 1898	–	–	–	–	–	–	–	–	–	8·9	1·63	0·14	0·26	1·07
14 January 1898	–	–	–	–	–	–	–	–	–	9·8	1·91	0·13	0·39	1·35
21 January 1898	–	–	–	–	–	–	–	–	–	12·7	1·88	0·17	0·44	1·64
28 January 1898	–	–	–	–	–	–	–	–	–	15·0	2·01	0·14	0·59	1·61
2 February 1898	–	–	–	–	–	–	–	–	–	8·3	1·68	0·10	0·23	0·89
25 February 1898	12·1	1·78	0·23	0·94	2·98	5·4	2·4	72·4	15·1	11·6	1·02	0·12	0·39	1·62
1 March 1898	7·7	1·40	0·12	0·28	1·61	4·7	2·4	49·4	8·4	7·9	1·36	0·09	0·18	1·24
18 March 1898	–	–	–	–	–	–	–	–	–	13·2	1·55	0·09	0·33	1·39
25 March 1898	–	–	–	–	–	–	–	–	–	7·6	1·53	0·11	0·34	1·89
1 April 1898	–	–	–	–	–	–	–	–	–	12·4	1·29	0·08	0·20	1·27
5 April 1898	–	–	–	–	–	–	–	–	–	8·9	1·75	0·09	0·19	1·65
15 April 1898	–	–	–	–	–	–	–	–	–	9·7	0·77	0·07	0·05	1·64
22 April 1898	–	–	–	–	–	–	–	–	–	8·3	1·15	0·09	0·37	1·50
26 April 1898	–	–	–	–	–	–	–	–	–	7·4	1·47	0·11	0·37	1·49
6 May 1898	–	–	–	–	–	–	–	–	–	8·1	1·18	0·10	0·27	1·85
13 May 1898	–	–	–	–	–	–	–	–	–	9·8	1·07	0·12	0·18	1·46
17 May 1898	–	–	–	–	–	–	–	–	–	7·1	1·05	0·08	0·40	1·32
24 May 1898	–	–	–	–	–	–	–	–	–	8·9	1·05	0·10	0·23	1·38
3 June 1898	–	–	–	–	–	–	–	–	–	7·8	1·15	0·08	0·17	1·35
10 June 1898	–	–	–	–	–	–	–	–	–	10·57	1·15	0·08	0·45	1·82
14 June 1898	–	–	–	–	–	–	–	–	–	10·1	0·97	0·07	0·22	1·30
5 August 1898	–	–	–	–	–	–	–	–	–	7·4	1·51	0·10	0·39	1·91
9 August 1898	–	–	–	–	–	–	–	–	–	11·5	1·55	0·11	0·46	1·28
Average	–	2·836	0·331	–	3·586	31·8	–	–	–	–	1·74	0·137	–	1·717
Purification per cent.	–	–	–	–	–	–	–	–	–	–	38·7	58·7	–	52·2

Effluents from Sewage Disposal Works—*continued.* 19 Oct. 1896.

WEEKLY AVERAGES.

(Quantities stated in Grains per Gallon.)

BED.						FINE BED.									
Nitrogen as		Suspended Matters.		Dissolved Solids.			Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as		Suspended Matters.		Dissolved Solids.	
Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.	Chlorine.	Free.	Albuminoid.	At once.	In four hours.	Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.
0·	0·026	4·8	1·9	55·3	14·5	11·3	1·85	0·07	0·24	0·730	0·	0·059	2·1	0·1	154·9	14·6
0·	0·032	11·9	5·7	60·5	13·4	10·9	2·01	0·52	0·36	1·226	0·	0·036	4·1	2·2	78·4	14·9
0·	0·027	6·8	4·1	57·0	12·9	9·1	1·83	0·173	0·33	1·200	0·	0·032	3·3	1·0	61·7	14·1
0·	0·031	10·8	6·8	61·7	15·8	10·1	2·19	0·197	0·37	1·24	0·	0·034	6·5	2·9	65·2	13·8
0·	0·043	12·1	6·2	64·2	19·0	10·4	2·29	0·153	0·39	1·09	0·	0·045	7·7	3·5	68·5	15·6
0·	0·045	14·5	7·9	65·3	15·4	10·4	2·40	0·13	0·30	0·91	0·	0·059	7·1	3·4	68·4	15·9
0·	0·050	10·3	4·9	55·8	12·3	9·2	1·79	0·10	0·04	0·51	0·	0·091	3·8	1·0	54·8	9·8
0·	0·047	11·2	6·3	58·4	12·1	9·9	1·84	0·09	0·11	0·63	0·	0·302	5·4	1·9	55·3	10·3
0·	0·051	16·2	9·0	57·7	9·4	9·9	1·27	0·06	0·03	0·39	0·	0·341	4·1	2·0	58·2	9·9
0·	0·058	9·7	5·3	58·1	12·6	7·8	0·86	0·07	0·01	0·46	0·	0·332	3·2	0·9	54·1	12·5
0·	0·045	5·7	3·7	58·9	10·8	7·5	0·92	0·07	0·04	0·53	0·	0·124	0·8	Tr.	55·3	12·1
0·	0·032	8·8	5·8	60·8	12·2	8·3	1·02	0·06	0·11	0·53	0·	0·178	1·2	0·6	61·2	11·5
0·	0·039	9·7	6·2	56·5	13·2	9·2	0·92	0·05	0·	0·41	Tr.	0·136	1·9	0·6	56·1	11·1
0·	0·031	8·9	6·8	62·3	12·8	8·7	1·07	0·06	0·	0·38	Tr.	0·137	1·5	0·7	55·9	11·7
0·	Tr.	13·1	8·4	56·0	9·1	12·2	1·05	0·05	0·09	0·51	Tr.	0·044	2·8	0·8	58·8	11·0
0·	Tr.	31·3	19·6	32·3	11·1	16·0	1·08	0·08	0·15	0·37	Tr.	Tr.	4·3	2·3	79·9	13·9
0·	Tr.	16·6	10·3	47·8	9·3	9·3	0·92	0·05	0·09	0·52	0·	Tr.	0·	0·	52·9	9·8
0·	Tr.	1·4	Tr.	70·3	10·9	10·5	0·56	0·05	0·	0·41	0·012	0·268	0·	0·	71·1	12·7
0·	Tr.	3·4	3·0	51·8	7·8	8·6	0·31	0·05	0·	0·41	Tr.	0·368	0·	0·	57·9	9·3
0·	Tr.	12·0	7·7	70·6	9·3	12·7	0·82	0·05	0·05	0·55	0·	0·054	3·6	2·6	66·8	9·4
0·	Tr.	8·3	6·7	51·1	11·6	8·4	0·96	0·05	0·	0·60	0·	0·38	1·5	1·5	52·9	9·9
0·	Tr.	9·5	5·0	62·6	10·7	10·4	0·62	0·05	0·	0·63	0·	0·044	2·7	1·8	56·1	9·9
0·	Tr.	10·2	6·4	50·8	12·8	9·0	0·98	0·05	0·05	0·73	0·	Tr.	5·1	4·8	49·9	10·0
0·	Tr.	5·4	3·4	54·7	9·9	7·5	0·54	0·06	0·05	0·51	0·	0·073	Tr.	Tr.	46·5	10·5
0·	Tr.	11·9	10·9	51·1	10·3	9·0	0·71	0·06	0·02	0·64	0·	0·	2·9	2·1	51·9	9·9
0·	Tr	11·7	8·9	51·7	10·5	8·8	0·87	0·06	0·	0·69	0·	Tr.	2·7	2·2	51·2	10·0
0·	Tr.	Bottle broken		Bottle broken		7·6	0·46	0·04	0·	0·64	0·	H. T.	H. T.	H. T.	58·4	11·4
0·	Tr.	14·5	9·4	56·5	10·7	9·7	0·55	0·04	0·	0·57	0·	0·073	1·4	0·4	58·7	12·8
0·	0·	9·8	6·8	51·5	10·6	8·0	0·70	0·04	0·14	0·53	0·	S.	4·9	3·8	50·0	8·5
0·	0·	9·0	5·8	57·0	11·8	8·4	0·56	0·05	0·11	0·46	Tr.	0·073	Tr.	Tr.	54·1	11·2
0·	0·	9·3	6·4	49·7	10·2	7·9	0·63	0·04	0·03	0·65	0·	0·037	0·	0·	50·5	11·2
0·	0·	11·0	7·7	63·6	11·8	10·5	0·66	0·05	0·03	0·65	Tr.	H. T.	H. T.	H. T.	59·3	10·4
0·	0·	11·0	5·2	57·5	11·2	9·2	0·63	0·04	0·06	0·56	0·	Tr.	Tr.	Tr.	53·2	13·0
0·	0·	9·6	8·0	55·1	10·5	7·5	0·71	0·05	0·05	0·75	0·028	0·082	0·	0·	60·4	10·9
0·	Tr.	11·4	5·6	66·2	10·8	11·4	0·84	0·05	0·	0·51	0·	0·091	–	–	–	–
–	–	10·6	–	–	–	–	1·07	0·071	–	0·618	–	–	2·4	–	–	–
–	–	66·7	–	–	–	–	62·3	78·6	–	32·8	–	–	92·5	–	–	–

19 Oct. 1898.

TABLE of Results of Analyses of Samples of Sewage and

H.—AT AYLESBURY.

(Quantities stated in Grains per Gallon.)

DATE OF COLLECTION.	CRUDE SEWAGE.									COARSE
		Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Suspended Matters.		Dissolved Solids.		
	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.	Total.	Volatile.	Total.	Volatile.	Chlorine.
29 January 1898	9·1	5·29	0·67	0·85	2·75	21·9	14·5	62·0	22·4	8·9
4 February 1898	12·7	6·94	0·94	2·05	4·10	28·1	18·9	69·0	21·0	12·9
12 February 1898	10·1	6·64	1·13	1·35	3·50	40·7	28·6	66·4	21·8	10·7
3 March 1898	7·9	5·40	0·47	0·78	3·53	28·4	19·4	57·3	16·8	6·2
11 March 1898	6·0	4·39	0·33	0·64	2·94	22·8	14·4	57·5	20·5	5·8
18 March 1898	5·3	5·60	0·43	0·77	4·23	30·0	26·5	50·9	14·0	6·0
25 March 1898	5·5	4·19	0·41	0·60	2·32	27·9	20·1	44·4	14·2	5·7
1 April 1898	6·1	3·78	0·96	0·69	3·85	18·6	13·8	62·1	22·0	6·7
6 April 1898	3·4	1·05	0·14	0·23	1·03	6·0	1·2	39·7	12·0	4·4
14 April 1898	7·8	5·35	0·47	0·93	5·44	28·1	21·8	57·4	23·3	6·9
21 April 1898	8·3	5·63	0·72	1·01	7·80	38·7	31·5	71·1	28·2	7,4
28 April 1898	8·2	5·86	0·68	1·01	7·21	36·7	28·9	61·6	20·9	7·2
5 May 1898	8·3	5·17	0·52	0·84	6·17	22·1	17·3	71·0	28·3	7·7
4 June 1898	7·9	4·57	0·26	1·36	3·62	36·3	23·9	50·7	16·9	7·7
10 June 1898	5·4	2·08	0·11	0·86	1·76	0·	0·	45·0	14·9	5·9
Average	–	4·79	0.55	–	4·02	25·7	–	–	–	–
Purification per cent.	–	–	–	–	–	–	–	–	–	–

DATE OF COLLECTION.	COARSE				
	Ammonia.		Oxygen absorbed from Permanganate at 80° F.		
	Free.	Albuminoid.	At once.	In Four Hours.	
29 January 1898	4·60	0·61	0·62	2·14	
4 February 1898	6·30	0·68	1·31	4·20	
12 February 1898	6·61	0·68	0·93	2·84	
3 March 1898	3·29	0·25	0·30	1·31	
11 March 1898	3·38	0·28	0·34	1·94	
18 March 1898	3·59	0·21	0·59	2·65	
25 March 1898	3·53	0·28	0·31	1·95	
1 April 1898	2·93	0·35	0·49	2·01	
6 April 1898	0·70	0·07	0·	0·86	
14 April 1898	3·45	0·28	0·49	2·54	
21 April 1898	4·29	0·44	0·77	3·56	
28 April 1898	3·71	0·40	0·74	3·76	
5 May 1898	3·41	0·30	0·55	3·48	
4 June 1898	3·11	0·22	0·76	2·31	
10 June 1898	1·54	0·06	0·23	0·88	
Average	3·63	0·34	–	2·46	
Purification per cent.	24·3	38·2	–	38·8	

I.—AT BLACKBURN.

7 January 1898	4·0	1·22	0·19	0·20	0·89	11·5	13·3	27·8	7·8	3·8	0·96	0·14	0·14	0·75
15 January 1898	6·1	2·03	0·30	0·59	2·11	20·5	13·2	44·5	11·9	5·5	1·44	0·15	0·42	1·30
21 January 1898	7·0	2·27	0·30	0·72	2·42	52·7	34·1	45·8	13·7	5·7	1·52	0·16	0·64	1·60
27 January 1898	8·4	3·58	0·33	0·80	2·94	32·7	24·0	56·5	18·5	8·0	2·06	0·30	0·69	2·29
1 February 1898	5·0	1·89	0·22	0·56	1·65	29·1	14·6	36·7	7·8	5·8	2·24	0·24	0·63	1·76
18 March 1898	2·6	1·05	0·10	0·09	0·91	20·4	3·3	26·8	6·6	2·7	0·42	0·03	0·	0·46
25 March 1898	4·8	1·64	0·17	0·37	2·22	20·5	13·6	40·3	12·0	5·1	1·54	0·12	0·17	1·24
2 April 1898	6·1	2·34	0·30	0·36	2·32	41·0	31·2	47·1	14·7	5·4	1·65	0·24	0·31	1·68
8 April 1898	6·2	2·48	0·23	0·41	2·40	29·8	16·2	51·5	19·3	5·4	1·98	0·11	0·30	1·60
14 April 1898	4·6	1·75	0·19	0·45	2·73	92·5	81·6	33·6	10·6	4·7	1·13	0·11	0·18	1·86
23 April 1898	6·6	2·24	0·33	0·85	3·47	28·2	19·4	50·6	23·5	6·0	1·93	0·18	0·48	1·98
30 April 1898	6·9	2·41	0·35	0·81	3·88	31·7	19·6	49·4	19·7	6·6	1·81	0·18	0·53	2·34
5 May 1898	6·3	2·30	0·27	0·71	3·08	34·0	22·4	48·9	19·0	5·6	1·66	0·16	0·44	1·78
12 May 1898	5·1	1·47	0·15	0·47	3·17	37·1	19·9	35·6	13·2	5·1	1·16	0·13	0·21	1·60
17 May 1898	6·2	2·00	0·29	0·66	3·83	31·8	20·4	49·4	20·1	5·6	1·47	0·19	0·51	2·45
27 May 1898	6·0	1·87	0·22	0·60	2·12	20·6	14·8	40·8	14·7	4·9	1·07	0·12	0·23	0·86
1 June 1898	4·5	1·09	0·21	0·29	2·52	29·0	19·4	31·4	9·0	4·7	1·05	0·10	0·23	1·83
Average	–	1·98	0·24	–	2·51	33·2	–	–	–	–	1·47	0·15	–	1·61
Purification per cent.	–	–	–	–	–	–	–	–	–	–	25·8	37·5	–	35·9

Effluents from Sewage Disposal Works—*continued.* 19 Oct. 1898.

WEEKLY AVERAGES.

(Quantities stated in Grains per Gallon.)

BED.						FINE BED.											
Nitrogen as		Suspended Matters.		Dissolved Solids.			Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as		Suspended Matters.		Dissolved Solids.	
Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.	Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.
0·	0·	5·2	0·9	33·5	21·3	8·6	2·53	0·16	0·47	1·90	0·021	1·00	0·	0·	75·7	16·2
0·	Tr.	8·3	4·6	74·1	18·8	9·4	4·00	0·23	0·65	1·22	0·021	Tr.	Tr.	Tr.	63·4	14·3
–	–	27·0	21·6	71·4	19·2	8·2	4·20	0·33	0·19	1·17	0·	Tr.	Tr.	Tr.	Tr.	Tr.
0·049	0·089	2·9	2·0	66·6	14·4	6·0	1·81	0·16	0·18	1·15	0·028	1·487	0·	0·	65·2	16·4
0·055	0·	3·4	3·3	68·0	15·4	5·9	2·35	0·21	0·	1·30	0·067	1·272	0·	0·	67·3	20·3
0·	0·	3·0	2·7	62·9	15·9	5·9	1·96	0·11	0·11	1·38	0·076	1·428	Tr.	Tr.	70·3	21·0
0·079	0·062	10·2	10·1	60·2	15·9	6·0	1·57	0·09	0·03	1·06	0·098	2·324	0·	0·	69·3	25·0
0·063	0·177	4·4	2·7	69·3	18·1	6·5	1·31	0·11	0·14	1·03	0·070	1·718	0·	0·	77·5	26·0
0·049	0·075	Tr.	Tr.	53·3	15·3	4·9	0·17	0·05	0·06	0·57	Tr.	1·665	0·	0·	64·9	23·3
–	–	3·6	6·7	58·7	17·0	5·9	1·32	0·16	0·37	1·43	0·105	0·375	Tr.	Tr.	54·3	15·5
0·	Tr.	9·6	9·0	67·3	23·4	6·4	1·74	0·18	0·31	1·31	0·098	0·098	0·	0·	57·0	15·3
0·	Tr.	13·7	10·2	60·5	20·0	6·3	2·62	0·26	0·32	2·72	0·112	Tr.	Tr.	Tr.	60·0	19·2
0·	Tr.	7·3	4·3	64·4	21·3	–	–	–	–	–	–	–			–	–
0·	0·	3·0	6·6	52·1	13·1	7·1	1·66	0·12	0·02	1·37	0·166	0·758	0·	0·	58·3	13·6
0·	0·057	Tr.	Tr.	47·3	13·0	6·0	0·94	0·04	0·02	0·54	0·008	0·950	0·	0·	51·5	15·0
–	–	7·3	–	–	–	–	2·01	0·16	–	1·29	–	–	0·	–	–	–
–	–	69·6	–	–	–	–	58·0	70·9	–	67·9	–	–	100·	–	–	–

WEEKLY AVERAGES.

Tr.	0·090	Tr.	Tr.	10·7	4·3	3·6	0·32	0·07	0·05	0·52	Tr.	0·105	Tr.	Tr.	27·3	7·3
Tr.	0·030	H. Tr.	H. Tr.	42·3	10·7	5·4	1·17	0·11	0·23	1·00	0·	0·042	Tr.	Tr.	41·6	8·6
Tr.	0·009	4·4	2·0	40·1	10·5	5·6	1·30	0·12	0·24	0·96	0·	0·016	1·5	1·1	40·9	10·1
0·	Tr.	9·1	7·3	47·5	11·9	7·7	1·97	0·24	0·47	1·65	0·	Tr.	H. Tr.	H. Tr.	49·9	11·6
0·	Tr.	6·0	5·1	43·1	8·3	5·8	1·67	0·16	0·30	1·12	0·	Tr.	2·5	1·5	41·6	9·6
0·042	0·358	Tr.	Tr.	35·4	10·0	3·8	0·18	0·02	0·	0·18	0·028	0·735	Tr.	Tr.	56·0	12·9
0·	Tr.	5·3	4·1	39·2	10·2	4·9	1·18	0·09	0·02	0·76	0·	0·026	Tr.	Tr.	42·5	11·7
0·	Tr.	5·5	3·2	44·9	13·6	5·9	1·20	0·10	0·07	0·94	Tr.	Tr.	Tr.	Tr.	44·9	11·9
0·	Tr.	7·3	5·2	42·6	14·1	5·5	1·27	0·09	0·12	1·07	0·019	0·024	Tr.	Tr.	42·4	12·5
0·	Tr.	5·1	3·3	31·9	10·0	4·9	0·75	0·07	0·05	0·87	0·049	0·041	Tr.	Tr.	34·3	9·7
0	0·	6·3	4·7	40·3	11·0	5·7	0·81	0·07	0·24	1·02	Tr.	Tr.	Tr.	Tr.	42·3	11·5
0·	Tr.	5·0	3·4	41·4	14·1	5·9	0·99	0·09	0·14	1·13	0·012	Tr.	Tr.	Tr.	41·5	12·3
0·	Tr.	3·8	2·0	41·0	12·8	5·9	0·84	0·08	0·08	0·86	Tr.	Tr.	Tr.	Tr.	40·6	10·3
0·021	Tr.	4·7	2·0	35·0	10·8	5·2	0·44	0·06	0·08	0·84	0·	0·144	Tr.	Tr.	39·8	12·5
0·	Tr.	5·0	3·6	40·3	13·0	5·5	0·80	0·09	0·10	1·17	Tr.	Tr.	Tr.	Tr.	41·6	12·8
0·	Tr.	H.T.	H.T.	34·5	11·4	4·7	0·56	0·04	0·06	0·46	0·038	0·180	Tr.	Tr.	38·1	14·0
0·	0·	4·3	3·9	33·7	10·4	4·6	0·59	0·04	0·	0·52	0·049	0·079	Tr.	Tr.	38·1	12·2
–	–	4·2	–	–	–	–	0·97	0·09	–	0·88	–	–	0·2	–	–	
–	–	87·3	–	–	–	–	51·0	62·5	–	65·0	–	–	99·4	–	–	

19 Oct. 1898. TABLE of Results of Analyses of Samples of Crude Sewage and Effluents from Sewage Disposal Works—*continued.*

J.—AT SUTTON, SURREY. GRANITE FILTER, &c.

(Quantities stated in Grains per Gallon.)

DATE OF COLLECTION.	CRUDE SEWAGE.									GRANITE FILTER.									
		Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Suspended Matters.		Dissolved Solids.			Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as		Suspended Matters.		Dissolved Solids.	
	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.	Total.	Volatile.	Total.	Volatile.	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.	Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.
7 February 1898	8·3	9·24	0·50	0·89	2·77	38·3	25·3	54·3	13·4	5·7	3·18	0·16	0·05	0·89	0·240	Tr.	Tr.	Tr.	53·1	9·7
17 February 1898	7·4	6·30	0·39	0·88	2·78	37·8	61·1	64·8	17·8	4·4	2·64	0·15	0·14	0·70	0·000	Tr.	Tr.	Tr.	45·4	11·7
10 March 1898	4·4	3·99	0·25	0·65	2·58	54·8	37·4	53·1	12·0	5·6	1·48	0·24	0·54	1·47	0·070	Tr.	Tr.	Tr.	54·3	11·1
16 March 1898	–	–	–	–	–	–	–	–	–	9·4	6·72	0·31	0·73	4·00	0·000	Tr.	40·3	29·0	58·7	13·5
Average	6·7	6·51	0·38	0·80	2·71	60·3	41·3	57·6	14·4	6.3	3·50	0·21	0·36	1·76	0·077	Tr.	10·1	7·2	52·6	11·5
Purification per cent.	–	–	–	–	–	–	–	–	–	–	46·2	44·7	–	35·0	–	–	83·2	–	–	–
	CRUDE SEWAGE.									CHALK FILTER.									
14 October 1898	6·0	6·82	0·63	0·75	4·45	70·2	50·8	53·1	21·7	6·6	5·25	0·50	0·52	3·18	0·0	0·0	Tr.	Tr.	59·5	28·5
Purification per cent.	–	–	–	–	–	–	–	–	–	–	23·0	20·6	–	29·6	–	–	100	–	–	–
	CRUDE SEWAGE.									SLATE FILTER.									
14 October 1898	6·0	6·82	0·63	0·75	4·45	70·2	50·8	53·1	21·7	6·5	6·33	0·42	0·98	3·85	0·0	0·0	Tr.	Tr.	62·2	27·0
Purification per cent.	–	–	–	–	–	–	–	–	–	–	7·12	33·3	–	24·7	–	–	100	–	–	–

TABLE of Results of Analyses of Samples of CRUDE EFFLUENT and FILTRATES from NORTHERN OUTFALLS.

J.—AT BARKING CREEK. WEEKLY AVERAGES.

(Quantities stated in Grains per Gallon.)

DATE OF COLLECTION.	CRUDE EFFLUENT.				FILTRATE.					
	Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as	
	Free.	Albuminoid.	At once.	In 4 hours.	Free.	Albuminoid.	At once.	In 4 hours.	Nitrites.	Nitrates.
26 Sept. to 6 Oct. 1898	–	–	–	3·631	–	–	–	2·128	–	·083
9 Oct. to 13 Oct. 1898	–		–	2·884	–	–	–	0·509	–	·215
16 Oct. to 20 Oct. 1898	–	–	–	3·295	–	–	–	0·502	–	·117
23 Oct. to 30 Oct. 1898	–	–	–	3·915	–	–	–	1·447	–	·021
30 Oct. to 6 Nov. 1898	–	–	–	4·420	–	–	–	1·546	–	·000
6 Nov. to 13 Nov. 1898	–	0·394	–	4·404	–	0·110	–	1·285	–	·208
13 Nov. to 20 Nov. 1898	–	0·368	–	4·122	–	0·097	–	1·125	–	·317
20 Nov to 27 Nov. 1898	–	0·403	–	4·336	–	0·091	–	1·208	–	·241
27 Nov. to 4 Dec. 1898	–	0·457	–	4·882	–	0·119	–	1·135	–	·175
4 Dec. to 8 Dec. 1898	–	0·435	–	4·745	–	0·109	–	1·070	–	·080
11 Dec. to 18 Dec. 1898	–	0·401	–	3·821	–	0·092	–	0·979	–	·120
19 Dec. to 23 Dec. 1898	–	0·398	–	4·277	–	·191	–	1·337	–	·006

TABLE of Results of Analyses of Samples of Crude Effluent and Filtrates from Northern Outfalls—*continued.* 19 Oct. 1896.

J.—AT BARKING CREEK. WEEKLY AVERAGES—*continued.*

(Quantities stated in Grains per Gallon.)

DATE OF COLLECTION.	CRUDE EFFLUENT.				FILTRATE.					
	Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as	
	Free.	Albuminoid.	At once.	In 4 Hours.	Free.	Albuminoid.	At once.	In 4 Hours.	Nitrites.	Nitrates.
7 April 1894	-	0·440	-	4·634	-	0·159	-	1·428	-	0·720
14 April 1894	-	0·521	-	4·627	-	0·128	-	1·027	-	0·212
21 April 1894	-	0·485	-	4·283	-	0·105	-	0·954	-	0·104
28 April 1894	-	0·507	-	3·977	-	0·107	-	0·800	-	0·745
5 May 1894	-	0·502	-	4·300	-	0·096	-	0·722	-	0·106
12 May 1894	-	0·394	-	4·105	-	0·090	-	0·844	-	0·1145
19 May 1894	-	0·308	-	3·879	-	0·055	-	0·814	-	0·0413
26 May 1894	-	0·303	-	3·877	-	0·059	-	0·657	-	0·1310
2 June 1894	-	0·401	-	4·033	-	0·086	-	0·703	-	0·1041
9 June 1894	-	0·308	-	3·247	-	0·069	-	0·611	-	0·0994
3 August 1894	-	0·365	-	3·195	-	0·094	-	0·685	-	0·2245
10 August 1894	-	0·329	-	3·217	-	0·081	-	0·661	-	-
17 August 1894	-	0·332	-	3·345	-	0·079	-	0·661	-	-
24 August 1894	-	0·271	-	3·132	-	0·057	-	0·661	-	-
31 August 1894	-	0·296	-	3·504	-	0·077	-	0·819	-	-
7 September 1894	-	0·390	-	4·495	-	0·082	-	0·785	-	0·0876
14 September 1894	-	0·356	-	3·530	-	0·087	-	0·712	-	0·1341
21 September 1894	-	0·419	-	4·080	-	0·186	-	0·767	-	0·0682
28 September 1894	-	0·521	-	3·540	-	0·103	-	0·745	-	0·1344
5 October 1894	-	0·553	-	4·006	-	0·244	-	0·808	-	0·1690
12 October 1894	-	0·519	-	3·648	-	0·243	-	0·828	-	0·0989
19 October 1894	-	0·439	-	4·242	-	0·117	-	0·781	-	0·0675
26 October 1894	-	0·460	-	3·964	-	0·132	-	0·740	-	0·0678
2 November 1894	-	0·292	-	2·497	-	0·080	-	0·540	-	0·3063
9 November 1894	-	0·406	-	3·726	-	0·089	-	0·762	-	0·2020
16 November 1894	-	0·259	-	2·412	-	0·079	-	0·491	-	0·8618
4 January 1895	-	0·447	-	5·240	-	0·150	-	1·190	-	1·6386
12 January 1895	-	0·434	-	4·045	-	0·162	-	1·103	-	0·8973
19 January 1895	-	0·441	-	4·202	-	0·112	-	0·817	-	0·9805
26 January 1895	-	0·352	-	3·762	-	0·085	-	0·742	-	1·1130
2 February 1895	-	0·362	-	3·695	-	0·098	-	0·801	-	0·6196
9 February 1895	-	-	-	4·016	-	-	-	0·971	-	0·4549
16 February 1895	-	-	-	4·281	-	-	-	0·891	-	0·3488
23 February 1895	-	-	-	4·967	-	-	-	1·047	-	0·0804
2 March 1895	-	-	-	4·524	-	-	-	1·293	-	0·
8 April 1895	-	0·370	-	3·048	-	0·096	-	0·810	-	1·0166
9 April 1895	-	0·418	-	4·095	-	0·124	-	0·810	-	0·6350
10 April 1895	-	0·358	-	2·571	-	0·104	-	0·905	-	0·6584
16 April 1895	-	0·401	-	3·238	-	0·123	-	0·705	-	0·7559
17 April 1895	-	0·261	-	3·429	-	0·080	-	0·762	-	0·94[illegible]
18 April 1895	-	0·343	-	4·476	-	0·104	-	0·952	-	0·8161
19 April 1895	-	0·385	-	4·381	-	0·080	-	1·048	-	0·7008
20 April 1895	-	0·348	-	2·857	-	0·104	-	0·762	-	0·6336

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TABLE of Results of Analyses of Samples of Crude Effluent and Filtrates from Northern Outfalls—*continued.*

J.—AT BARKING CREEK. WEEKLY AVERAGES—*continued.*

(Quantities stated in Grains per Gallon.)

DATE OF COLLECTION.	CRUDE EFFLUENT.				FILTRATE.					
	Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Nitrogen as	
	Free.	Albumihoid.	At once.	In Four Hours.	Free.	Albuminoid.	At once.	In Four Hours.	Nitrites.	Nitrates.
4 May 1895	-	-	-	3·592	-	-	-	0·753	-	-
11 May 1895	-	-	-	3·576	-	-	-	0·961	-	-
18 May 1895	-	-	-	3·867	-	-	-	0·865	-	-
25 May 1895	-	-	-	3·657	-	-	-	0·962	-	-
1 June 1895	-	-	-	4·009	-	-	-	1·013	-	-
8 June 1895	-	-	-	3·399	-	-	-	0·841	-	-
15 June 1895	-	-	-	3·247	-	-	-	0·872	-	-
22 June 1895	-	-	-	3·496	-	-	-	0·898	-	-
29 June 1895	-	-	-	3·441	-	-	-	0·566	-	-
6 July 1895	-	-	-	3·576	-	-	-	0·614	-	-
13 July 1895	-	-	-	3·282	-	-	-	0·572	-	-
20 July 1895	-	-	-	3·219	-	-	-	0·531	-	-
27 July 1895	-	-	-	2·852	-	-	-	0·490	-	-
3 August 1895	-	-	-	3·359	-	-	-	0·538	-	-
10 August 1895	-	-	Filter not used.		-	-	Filter not used.		-	-
17 August 1895	-	-	-	2·810	-	-	-	0·450	-	-
24 August 1895	-	-	-	2·928	-	-	-	0·485	-	-
31 August 1895	-	-	-	2·670	-	-	-	0·467	-	-
7 September 1895	-	-	-	2·688	-	-	-	0·503	-	-
14 September 1895	-	-	-	2·573	-	-	-	0·470	-	-
21 September 1895	-	-	-	2·746	-	-	-	0·461	-	-
28 September 1895	-	-	-	2·889	-	-	-	0·491	-	-
Average	-	0·894	-	-	-	0·108	-	-	-	-
Purification per cent.	-	-	-	-	-	72·6	-	77·8	-	-

Colonel DUCAT; called in, and Examined.

Col. Ducat
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2184. (*Chairman.*) I think you are Colonel Ducat?—Yes, my lord.

2185. I do not know whether I might ask you to give us a general account of the principle upon which your system is founded?—I will. My system of sewage purification has for its principle the taking of the sewage direct from the sewer, as fresh as possible, and without any preliminary treatment with chemicals or otherwise, submitting it at once, in the presence of air, to the action of micro-organisms, which break down and liquefy all the solids, and finally act on the impurities in solution. In my process I make use of the aerobic microbes only, and the main feature of my invention is that I supply these aerobic microbes, in all stages of the process of purification, with as much oxygen as they require, by natural means.

By omitting a first treatment of the sewage in a submerged and airless chamber, as is necessary in most of the bacterial methods of treatment of sewage, I avoid all cultivation of pathogenic anaerobic microbes, any of which, coming, as they are certain to do in any sewage taken direct from a sewer, are at once subjected to conditions most unfavourable to their growth and propagation, and to the action of the aerobic microbes most inimical to them.

The construction of my filter is such that the aerobic microbes may be said to be acting on the sewage practically in the open air, and the length of time of exposure of the sewage to treatment can be regulated to any required extent by merely increasing the depth of the filter. The sides or walls of the filter are so open and porous that air can pass freely through them, though they are capable of supporting and retaining the filtering material; and air is distributed throughout the body of the filter by means of air-pipes, forming aerating layers at intervals over the whole area.

The filtering medium itself is designed partly to collect, cultivate, and house immense numbers of bacteria to act on the sewage; and partly to minutely sub-divide the sewage into very thin films when passing through it, and, in this state, subject it to the action of the microbes, in the presence of air. It will thus be readily understood how, by judiciously sizing and arranging the filtering material, the sewage can be so finely separated and so obstructed and retarded in its passage through it, that the sewage shall be long exposed, in the most attenuated form, to the purifying action of the micro-organisms, under the most favourable conditions conceivable; and by slightly raising the height of the filter this purifying action can be prolonged to give any required degree of purity in the effluent. The water from no rivulet or cascade on a mountain side could be more thoroughly aerated and oxidised in miles of natural channel, than sewage or water can be in

a few feet of this filter, the flow through which can be made to occupy an hour or more, during all which time the action of millions of carefully collected and stored microbes is brought to bear on any putrescible matter in the liquid under treatment. The working of the filter has been designed to follow as strictly as possible the working of Nature herself, the conditions only being intensified to meet the artificial circumstances under which pure water is converted into foul sewage.

Sewage or water, subjected to treatment under the above-described specially designed conditions of exposure to air, would, in great cold, become frozen; and in the ordinary cold of an English winter, sewage, no matter how warm it may be on arrival at the outfall of the sewer, must in the filter, if not provided against, soon be reduced in temperature below 37° Fah., the limit below which bacterial action is suspended; consequently arrangements have had to be made to effect the necessary aeration in winter with air which has been artificially warmed. This has been done by roofing the filter, and screening the walls from the direct action of the atmosphere when the temperature falls below 40°, and by receiving the required air supply through flues in the filter, in which hot water pipes have been laid, by which means a strong indraught of air is caused by the difference of the temperatures between the air in the open and that in the flues, and the cold air, so drawn in, is heated by the hot water pipes until it rises into the filter, and a constant current of fresh air is thus supplied to the microbes, and the filter can be worked with efficiency in Canadian frost. This warm air supply, which at first presented a great difficulty, has been converted into an advantage that no other filter possesses, and without which no high bacterial purification can be obtained in winter.

2186. Then could you describe the construction of your filter?—The filter should be raised on a floor of cement concrete, sloped to drain from the centre outwards towards the side walls, through which the purified sewage will run off into an effluent channel, which should be constructed in the concrete floor.

The main walls of the filter, which may be of any required height, 5 feet, 8 feet, 10 feet, up to 15 feet or more, will rest on the concrete floor, as a foundation, and may be one foot thick, built of agricultural drain pipes, set in cement, having the necessary masonry pillars or iron framework to strengthen them to support the weight of the filtering material.

On the concrete floor the hot air flues also should be built, running transversely across the filter, and through the main walls on each side, and connected with a small boiler shed, in which the hot water system, for use in winter, will be placed.

The filtering material may be of very hard vitrified cinders or clinker from a furnace or refuse destructor, or of clean pebbles, or any other clean rough material of suitable size that will form a good nidus for microbes, and will not itself disintegrate under the necessary exposure to air and water. This filtering material must be riddled or screened to the sizes required, viz., about ½ to ¼ inch for the upper part of the filter, and about ⅛th inch for the bulk of it, with stuff about 1 inch in size for the drainage layer at the bottom of the filter, and for the aerating layers as filling between the air pipes. No very fine grained material for mechanical screening of the sewage is necessary at all.

The main walls of the filter should be enclosed with removable shutters, or a thin brick wall, in which a number of doors are constructed to allow of the admission of plenty of air, and the whole should be roofed over with a light iron or other roof, having ample ventilation in it.

The sewage will be brought to the disposal works in an ordinary covered sewer, when it will be sub-divided into smaller channels to suit the number of filters required for the treatment of the sewage to be dealt with. On one main wall of each filter its own feeding channel will be built of cement, and will be furnished with little weir sluices and shoots discharging the sewage into iron distributing channels placed about 1 to 1½ feet apart, and extending transversely across the top of the filtering material. These distributing channels will automatically tip and discharge their contents, when full, and right themselves again when empty, so that no sludge will collect and settle in them; and the whole working of the filter will be as nearly automatic as possible, human agency merely being wanted to see that no channel gets blocked or fails to work properly. When a filter has been suitably designed for the amount of sewage it has to treat, and the weir valves have been adjusted to the flow, no constant supervision is wanted, as there are no valves to open or shut.

The sewage before being run on to the filter must be subjected to the ordinary screening usually adopted at sewage disposal works, and for this screens will have to be provided, and where there is much road detritus to be dealt with it will be well to construct suitable silt traps which are simple and not costly.

2187. Then would you describe the method in which the filter works?—From the nature of the filter and its requirements it is clear that it cannot be constructed like an ordinary submerged filter of any indefinite size, but that to secure perfect aeration and for convenience of construction and working the dimensions of each individual filter must be limited, and in working on a large scale I would limit my dimensions to 126 feet long by 36 feet wide, which would give a filter capable of treating 100,000 gallons of sewage daily, and I would make such a filter as this my unit. For a town having a million gallons of sewage daily to dispose of, 10 units would be wanted, just as for such a town 10 precipitating tanks might be required for a precipitation process, and there is no practical difficulty whatever in applying the system to a city of any size, and no risk or uncertainty of the bacterial action, as there might be, if the size of the filter, and consequently the efficiency of its aeration, were to vary indefinitely with the volume of sewage to be dealt with in each case.

As a general rule it may be taken that each square yard of filtering area will satisfactorily purify 200 gallons of sewage daily, or one acre of filter suffice for one million of gallons a day, and the depth of the filter may vary according to the nature of the sewage to be treated on it and the amount of purity required in the effluent. Where the effluent is to be discharged into the sea or brackish water, as at London, a depth of filter of five feet would in most cases suffice; a filter eight feet deep will give an effluent pure enough to meet the requirements of any river authority and to go into any stream no matter how small, but if the effluent is to go into a small stream the water of which is liable to be used for dietetic purposes, it would be well to make the filter ten feet deep or more. For the treatment of the waste water alone of certain trades a filter 12 or 15 feet deep may be necessary.

In practical working the action of the filter is simplicity itself. The sewage is automatically distributed over the surface of the filter, and the purified effluent runs off through the outlets in the bottom of the walls into the effluent channel in a constant flow without the intervention of a valve anywhere or any human agency to direct the flow, the supervision of one man over about ten large filters being recommended merely to see that nothing is going wrong.

This constant flow and simplicity of action are of more practical value and importance than may at first sight appear. In any submerged filter from which air is naturally excluded it will be found that when the outlet valve is first opened, and the discharge of the filter is at its maximum, the purity of the effluent is very much less, as much as 50 per cent. less, than it will be when the filter is nearly empty and the filter has become aerated. In the first outflow it is not uncommon for a smell of sulphuretted hydrogen to be disagreeably perceptible, while the final draw off from the same filter may be pure enough to go into a stream, and with such constantly recurring variation in purity as this, which is unavoidable in the intermittent discharge from a submerged filter, it is evident that if a uniform standard of purity is to be maintained in the effluent, it must be submitted to further treatment. Again, the simplicity of the constant flow requiring no human agency to direct it, is very important, not merely ensuring more reliable results, but in some cases constituting the difference between success and failure, practical working and impracticability. This will be made more clear if, with your permission, reference be made to other methods of working. Take, for instance, the proposed treatment by eight or ten double sets of bacterial filters in an eight-hour cycle of rotation, which was one of the recent methods advocated. By this arrangement, which was adopted in supercession of a previously proposed one, in which only one pair of filters of any indefinite size are required, was supposed to be sufficient, it was proposed that in every case, no matter how small the quantity of sewage to be treated might be, eight to ten double sets of filters should be provided, and that each filter in its turn should be filled in one hour, remain full for two hours, be emptied in two hours, and remain empty for three hours for aeration before filling again, great stress being laid on

Col. Ducat.
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this three-hour period of aeration, which was considered absolutely necessary to give a maximum of efficiency. This eight-hour cycle of rotation under the unequal flow of the sewage of a district, rendered more variable by storm water, was found in practice to cause such complication and difficulty in the opening and closing of the valves in the different filters all through the day and night as to be altogether unworkable, and this arrangement was abandoned. An attempt was then made to adhere to the same cycle of rotation and retain the three-hour period of aeration, but with fewer filters and less complication, but this also being found impracticable, all pretence at regular aeration has been thrown aside, and continuous flow through submerged tanks, making any aeration absolutely impossible during that time, has been advocated, so that not only has the maximum efficiency of the process been lost, but all efficiency at times has had to be sacrificed to the practical difficulties of working, showing the importance attaching to the simplicity of working of any system.

The advantages of the simplicity of action of my filter are most marked in dealing with storm water, which, in almost every case, presents such difficulty. In any chemical process the dilution of the sewage makes proper subsidence of the solids difficult and slow, so that the size and number of the precipitation tanks has to be increased to give sufficient period of quiescence to allow of precipitation at all, and the size of the ordinary submerged filters must be increased to enable filtration to be carried on. This provision for dealing with storm water is so costly that it is seldom, if ever, made; and Manchester, in their last year's report, state that on twenty-one occasions during the year, for a total period of 128 hours, they suspended all treatment of the sewage of the city. In any bacterial treatment of sewage in submerged filters and cycles of rotation for aeration, the cost of the filters will be increased by about 60 per cent., and the difficulty of working is so great as to be almost insuperable. In a complete anaerobic process such as that of the septic tank, where the sewage must necessarily stand for many hours subject to the action of the anaerobic microbes, there does not seem to be any solution of the difficulty of treating storm water. If the storm water is allowed to enter the septic tank at all, it must displace a like quantity of undiluted and partially treated sewage; and, assuming that the tank is designed to hold twenty-four hours' flow of normal daily discharge, and that, say, 2½ times the normal bulk of sewage is to be treated in time of storm, it follows that, at the commencement of a storm, the whole of the undiluted sewage in the tank, requiring properly twenty-four hours to complete its clarification, may be washed out into the river in an hour or two in a high state of putrefaction, and the tank may be filled with cold rain water, so little diluted with sewage, as to greatly retard anaerobic action; consequently after every single storm of rain, not only will the river be dangerously polluted at the time, but it will be many days before the tank will recover its tone, and give its maximum efficiency. Now, in the case of my filter, no difficulty arises, and purification will continue much as usual. The rain water does not add to the impurities in the sewage, which is what the microbes have to deal with, and the dilution of the sewage will make it easier to purify. The filtering material is so open that 2½ times the normal sewage, or even a much larger dilution, could pass through it without the slightest difficulty, and the rate of filtration would still be slow enough for the microbes to act satisfactorily, and my filter thus gets over the storm water difficulty, as no other known process can do.

In practical working my filter offers unique advantages to a Sanitary Authority using it, to a River Authority whose duty it is to guard against the pollution of its streams, and to the country generally, which is deeply interested in the purity of the rivers.

To the Sanitary Authority of a district, its extraordinary simplicity and economy, when known and understood, must recommend it highly. The first outlay on the filters will, I believe, in most cases be less, generally much less, than the necessary outlay on the works of any other efficient method of sewage disposal, and the cost of the actual treatment of the sewage is so small as to leave little to be desired. No chemicals are used, no sludge has to be precipitated or dealt with, consequently no sludge pumps or presses have to be provided or worked, no washing or renewing of the filtering material is necessary, and the manual labour required is reduced to a minimum, one man can superintend the purification of one million gallons daily, and this man's wages, with a small charge for coke to warm the air supply in winter, and such small contingent charges as are inseparable from all works of this nature, will comprise the entire expenditure. To put the cost of construction of the filter and the expense of purifying sewage into actual figures which can be relied on, is very difficult, practically impossible, as the local conditions and prices of labour and materials vary so much; but taking what I think is a fair average over England, the following may be taken as the estimated cost of a filter to treat 100,000 gallons a day, and the expense of purifying sewage, when working on a fairly large scale, viz., Masonry of filter, with clinker filling, per square yard, say, £1 10s.; distributing channels, say, 3s.; roof, say, 6s.; heating, say, 15s.; total, £2 14s., say, £2 15s. to £3 per square yard of filter.

Cost of purifying per million gallons:—

One man, at 28s. a week, 4s.; fuel, 5s. a day—for six months in the year, 2s. 6d.; contingencies, say, 6d.; total, 7s. per million, or 1·12d. per 1,000 gallons of sewage purified. It will be understood that the above is for the cost of purification only of an ordinary sewage. If the sewage to be treated contains an unusual amount of road detritus, there will be no difficulty whatever and very small expense, either in works or labour, in dealing with it; but the cost of its removal, such as it may be, will be extra. The above charges would, in all ordinary cases, cover the cost of treating a sewage with trade waste in it, but it is not possible to say what extra expense might be incurred in very special instances. In the case of an acid sewage, the addition of a little lime in the sewer to neutralise the acid, would be a very small matter and scarcely add appreciably to the expense of purification; in the case of such a sewage as that of Wolverhampton, it might, I do not say that it certainly would, be necessary to neutralise with lime and precipitate the iron with the sludge; in which case the additional cost would be considerable, but the effluent could still be purified more perfectly, and at less expense, than it could be by any other process. It does not follow that a sewage, containing a mixture of the waste of many trades, is difficult to treat, but in most cases of that kind it would be safer to erect a small trial filter, and ascertain practically what preliminary treatment, if any, is necessary to get good results.

Now to compare the cost of purification by my filter with other methods of treatment I will mention a few cases, if I may be permitted to do so. At Manchester they pay comparatively little for their sewage disposal; in 1896 the cost per million was £2 14s. 3d.; and in 1897, by reducing the amount of chemicals used for precipitation, the cost was reduced to £2 11s. 9d.; but it is stated in their Annual Report that they did not produce an effluent up to the standard of purity required by the Mersey and Irwell Joint Rivers Board on one single day in the year; consequently as they did not render their sewage non-polluting, as they did not satisfy the River Authority, and as they have not saved themselves from legal proceedings, the results cannot be considered satisfactory. In London the cost of partial purification amounts to £3 13s. 5·17d. per million, and the Joint Sewerage Board at Richmond in Surrey spend £3 4s. 10½d. per million; but both these authorities discharge their effluent into the tidal water of the Thames, and do not aim at high purification; but, I believe, both are anxious to improve on the results they obtain. When we come to effluents discharged into streams, we find that at Weybridge and Oatlands, with modern and good works, they spend, in chemicals alone, £2 15s. per million gallons, and this will not represent nearly half the cost of their sewage disposal; at Wood Green the cost per million is £5 7s. 8d.; at Hendon they are now paying more than £7 per million gallons; at Hertford the cost of their sewage disposal is about £9 per million; and at Willesden, where they have very lately erected at great cost works on the latest pattern for treatment on what was known as the International System, the cost of purification per million largely exceeds any of those mentioned above, and the resulting purification, though the effluent is treated over a large area of land, is, I understand, not particularly high or satisfactory.

From a pecuniary point of view there can be no doubt of the advantages gained by a Sanitary Authority adopting my system if really anxious to purify their sewage—but this is not the only gain. Where the purification has to depend largely on human agency, the Authority must be at the mercy of their servants, and where chemicals have to be added, so many grains to the gallon, the greatest nicety is necessary to adjust the quantity of chemicals to the ever varying quantity of sewage coming down the sewer, and this nicety is seldom even aimed at,

much less attained, but, on the contrary, the Sewage Works Superintendent frequently stints his chemicals to show how carefully and economically he can work, with the result that pollution of the river takes place, and the reputation of the Sanitary Authority suffers.

The benefit to a River Authority will be great, in that the supervision now so necessary to prevent scamping and hidden pollution, will be so reduced and simplified as to be little trouble or expense, and the total and absolute purification of all the sewage of a district so far ensured, that it will be actually more trouble to divert and not treat the sewage than to run it through the filter and treat it satisfactorily. At present the cost of treatment of sewage is so great that the temptation to pass it surreptitiously into a stream and so save chemicals, sludge, and the other expenses of the process employed, is too strong for the morality of most Superintendents of Sewage Works, and those who succumb to this temptation, being always on the works, and studying how to evade their duty, naturally become adepts at deception and concealment, and it requires a very clever Inspector to detect their backslidings on his casual and naturally rather hurried visits. The facility with which inpection can be baffled was illustrated at Coventry, where, for years, the treatment of their sewage was exhibited to experts, not only in England, but from all parts of the Continent, who went away quite convinced that 2½ millions of gallons of sewage daily could be perfectly treated and purified on 8 acres of land if properly prepared and worked. It fell to my lot afterwards to ascertain that during all those years only 70,000 gallons out of the 2,250,000 gallons daily ever went to the 8 acres of land at all, and that the whole of the rest was discharged direct and untreated into the river through a hidden channel under the works. This is only one of many instances I have known of like deceptions which have been very difficult to trace.

Again, in the case of polarite, advantage has been taken of the peculiar property possessed by this material absorbing and giving off oxygen to delude people into belief that a filter of this substance can purify 1,500, 2,000, and even 6,000 gallons of sewage tank effluent per square yard per diem. It is possible that such quantities can be passed through a polarite filter for half an hour or so while there is still oxygen stored in it, and by this means a filter that has been carefully prepared, dried, and aerated can be utilised during the short period of an Inspector's visit, but after a few hours' working no more purification will take place until the filter has had a rest long enough to dry it thoroughly throughout, and allow the absorption of fresh oxygen, and in the meanwhile pollution takes place. Under these conditions, and with several filters previously prepared and kept ready, an Inspector would have to spend many hours, probably more than a whole day, to detect pollution and trace its cause. This pollution is certainly going on undetected to this day

There are very few Sewage Works throughout the country where a back-door is not provided by which, during an Inspector's visit, the flow of sewage can be reduced, and an improved effluent, for a sample, be produced when wanted; and by which at other times the cost of treating the bulk of the sewage can be saved altogether. And this scamping is quite as common in the case of Sewage Farms as in Precipitation Works, and, owing to the larger area to be inspected, is more difficult to detect. I have found the whole sewage of a district being discharged direct into a stream through one of the farm carriers, because the crops of the land were ripe, and to irrigate with sewage would do them harm.

Now in the case of my filter none of these difficulties could occur, and an Inspector can see at a glance all that is going on. He can see the sewage coming on to the filter, and, in about half an hour, can see the same sewage running out of the filter purified, and can tell, with certainty, what purification is being obtained. The benefit to the whole country will be great, in that the purification of sewage will be made so cheap and simple that universal purification can be, and ought to be, enforced, and all inducement and all facilities for scamping being removed, the rivers throughout the land should be really purified at all times.

2188. Where could we see your process in operation?—At Hendon at present. The process of purification by my method can be seen in work at Hendon, where a continuous flow of about 3,000 to 4,000 gallons of sewage is being daily treated on each of the two filters there erected. The sewage of Hendon is a very strong domestic sewage (nearly every house in the district being fitted with a water-closet), mixed with a most troublesome trade refuse from the laundry factories, of which a large number are to be found in Hendon for the laundry work of London. This refuse, consisting of the waste from chemical soap, so freely used in laundry work, is very greasy and difficult to deal with, as is shown by the fact that the International treatment would not purify it, and by the elaborate but not very successful treatment now adopted, by which, after a double admixture of chemicals and the precipitation of sludge in very large and perfect tanks, the sewage is twice filtered, once through sand, coke, and burnt ballast filters, and finally through polarite filters. This treatment, which admittedly costs the ratepayers over £7 a million gallons does not give results equal to those from my filter. My experimental filters at Hendon are not very large, but they perfectly and fully represent my method of treatment; they treat a continuous flow of sewage, day and night, just as they would do the total sewage of a small district, and the principle would not require to be changed in any way whatever to treat the sewage of London; each individual filter would be made a little larger, viz., 126 feet long by 36 feet wide, or three times the width of the filter at Hendon, and of the same depth, to treat 100,000 gallons a day each, and the number of such filters would be multiplied to deal with the quantity of sewage to be treated, whatever the quantity might be; but no working detail would need to be changed in the least from the examples shown at Hendon.

The sewage at Hendon, by analysis, is one of the worst in England, about ten times worse than the sewage of London, and about the same in character as that of Nuneaton, where the trade refuse from the hat making industry gives very much the same kind of greasy sewage which is there found so difficult and so expensive to treat.

I attach analyses, both chemical and bacterial, of the sewage and of the effluent from my filter at Hendon, which I will leave to speak for themselves.

TABLE showing the results of the Bacteriological Examinaton of (1) Crude Sewage as applied to Filter; (2) Effluent from Aërated Bacterial Filter; and (3) Effluent from Secondary Sand Filter.

Description of the Sample.	Total Number of aërobic bacteria in 1 cc. of Sample.	Number of Spores of aërobic bacteria in 1 cc. of Sample.	Number of aërobic bacteria causing liquefaction of gelatine in 0·00001 cc. of Sample.	Number of Colonies not to be distinguished from B Coli in Phenalgelatine Plate containing 0·0001 cc. of Sample.	Spores of Anærobic B Entiritidis Sporagenes (Klein).
Crude Sewage as applied to filter, 4th Oct. 1898.	12,000,000	1,420	22 (2,200,000 in 1 cc.)	12 (1,200,000 in 1 cc.)	+0·1; 0·01; & 0·001 cc. −0·0001 cc. At least 1,000, but less than 10,000 per cc.
Effluent from aërated bacterial filter, 4th Oct. 1898.	25,000, Reduction over 99 %.	22, Reduction 98 %.	No liquefying Colonies in 0·00001 cc.	No Colonies resembling B Coli in 0·00001 cc.	+1·0 cc. −0·01 & 0·1 cc. At least 1, but less than 10 per cc. Reduction over 99 %.
Effluent from secondary sand filter, 4th Oct. 1898.	113,000, Reduction 99 %.	12, Reduction 99 %.	- - ditto - - ditto - -	- - ditto - - ditto - - - -	+1·0 & 0·1 cc. −0·01 cc. At least 10, but less than 100 per cc. Reduction 99 %.

True Copy. *Walter M. Ducat.*
10 Oct. 1898.

(Signed) *A. C. Houston.*
8 Oct. 1898.

TABLE showing the results of the Chemical Examination of (1) Crude Sewage as applied to Filter; (2) Effluent from Aërated Bacterial Filter; and (3) Effluent from Secondary Sand Filter.

Results stated as parts per 100,000.

Description of the Sample.	Oxygen absorbed from Permanganate in four hours.	Free Ammonia.	Albuminoid Ammonia.	Sum of the Ammonia (free and Albuminoid).	Oxidized Nitrogen.	Remarks.
Crude sewage, as applied to filter, 4th Oct. 1898.	14·72	8·7	1·6	10·3	—	A foul sewage, emitting a most offensive smell.
Effluent from aërated bacterial filter, 4th Oct. 1898.	0·78 Reduction, 94 %.	0·3 Reduction, 96 %.	0·094 Reduction, 94 %.	0·394 Reduction, 96 %.	0·477	As transparent and free from odour as an ordinary drinking water.
Effluent from secondary sand filter, 4th Oct. 1898.	0·86 Reduction, 94 %.	0·156 Reduction, 98 %.	0·096 Reduction, 94 %.	0·252 Reduction, 97 %.	0·612	- - ditto - - ditto.

True Copy. *Walter M. Ducat.*
10 Oct. 1898.

(Signed) *A. C. Houston.*
8 Oct. 1898.

Since I prepared the foregoing I have received this paper this morning. I was not aware that the experiment was being made.

Oct. 4th 1898.

(A.) 1ce of Hendon crude sewage injected subcutaneously into a guinea-pig by Dr. Klein (A).

(B.) 1ce of the effluent from Colonel Ducat's aerated bacterial filter, injected subcutaneously into a guinea-pig by Dr. Klein (B).

The following day:

(A.) Large swelling and very quiet.

(B.) Slight swelling, no uneasiness.

Third day:

(A.) Dead. Appearances partly typical of malignant œdema and partly of Enteritidis.

(B.) Swelling disappeared, eating well.

Final note:

(B.) Completely recovered.

A. C. HOUSTON, M.B., D.Sc.

Oct. 19th 1898.

2189. (*Sir Richard Thorne.*) Might I ask one question before we depart from these tables that Colonel Ducat puts in. I notice that the tables relate to the examination of crude sewage as supplied to the filter; secondly, of effluent from the aerated bacterial filter, which I presume is the filter you have described to us?—It is.

2190. And then, thirdly, what you have not described to us, of an effluent from a secondary sand filter?—That I have discarded; it was an experimental thing. I thought it might improve matters to put it through a secondary filter of sand, but we have gone backwards instead of forwards.

2191. Then you are not attaching any importance to that whatever?—No.

2192. (*Chairman.*) Are you anxious, as a matter of principle, to eliminate anaërobic microbes altogether?—Certainly.

2193. Do you believe that anaërobic microbes are mischievous things in themselves?—I believe they are, most of them.

2194. And therefore you believe that any anaërobic treatment must be attended with some danger?—That is my opinion. And I might say here that the reason why I believe that sand filter failed is because it is anaërobic. It was a filter that you fed from below—upward filtration; the filter was submerged, and as a proof it has depreciated all the way round, it has not given such good results as I had from a single filter.

2195. (*Professor Ramsay.*) Was the sand filter subsequent to the other filter?—Subsequent to the other filter.

2196. Not substituted for it?—No, subsequent; to filter the filtrates from the first one.

2197. (*Chairman.*) You have, as I understand, screens to your filters to keep back the solids?—I have the ordinary screens, as you have in all sewage works as a rule; I do not profess to treat boots and brushes and things of that sort.

2198. But the solids that are kept back by the screens must accumulate behind those screens?—A screen is used in almost every sewage farm, and it is cleaned almost every day with a rake.

2199. It is cleaned out every day?—It is cleaned out every day; it is a very small matter; there would probably be a wheelbarrowful or two.

2200. But supposing you were dealing with an enormous amount of sewage, cleaning out the solids every day would not be a very small affair?—Of course it would be in proportion to the amount of the sewage, naturally; you cannot treat the sewage from a large town without a certain outlay, of course.

2201. You have, of course, to prevent the solids getting on to your filters?—I would not say that. I have had large pieces of fœcal matter. I have had a fowl's head and things of that sort, but it is to take out the bigger things which cannot go into the filter itself. As a matter of fact the screen retains very little of the fœcal matter or anything of that sort, and there is a very large amount of sludge in the sewage that comes on to the filter; it does not practically lessen the sludge at all, or very slightly indeed.

2202. What is the size of the screen?—About ½in. ordinary straight rails, about half-an-inch apart. Of course, I must not mislead you. I say that would be the screen. What I have at present is a wire rose, because I have only this small filter, standing in the sewer I have a rose of wire about ½in. mesh.

2203. As regards storm water, of course in case of a storm the flow through the filters must be very much accelerated?—It would be, of course.

2204. But you do not think that that would affect the quality of the effluent?—We have just had very heavy rain at Hendon; the sewage generally flows under a head of about three inches; it has been flowing under a head as much as this table, two feet six inches, and it has not made the slightest difference.

2205. You think that owing to the dilution of the sewage the effluent is as good as the effluent that comes from the filters in an ordinary time, although, of course, it passes through much more quickly?—I do not think there is any perceptible difference. It might not perhaps analyse quite so highly. You see I have analyses here of more than twice the purity required by the Rivers Board, and I have not the slightest doubt that an effluent which will analyse well within the mark of what the Rivers Board required will be obtained even in storm.

2206. What is done with the solids; are they put back into the earth; are they used as manure or anything of that sort?—They do not exist; they are all liquefied.

2207. But I mean the solids kept back by the screen?—Yes, they are dug in.

2208. Your sewage effluent—what becomes of that?—That now runs into the River Brent.

2209. No use is made of it?—It is full of manurial value, but at present I do not use it. But it has as much manurial value as any raw sewage, in a much more convenient form for plant life.

2210. It would have a manurial value?—A very high manurial value.

2211. (*Mr. Killick.*) Is that the largest installation you have erected at Hendon?—Yes.

2212. How long have they been in work?—Well, it is difficult to say quite. I think my cinder filter has been working continuously since April; the pebble filter has been changed on and off at different times, but a little longer, I think. I had to stop the pebble filter for some time, because they were cleaning their sewer at Hendon. It is a large iron sewer, and they had about 15in. in it of road detritus at the bottom; in the manhole from which my filter draws its supply they put up the apparatus for raking these sewers, and they closed my pipe for me for about a month or six weeks, and did me a good deal of harm.

2213. It is rather difficult to judge whether the filter has lost capacity to any extent?—It is at present, but I worked my filter last year before I drew the coke from March to November, and there was not the slightest depreciation of any kind. In fact, my effluent got better and better.

2214. Do you suppose it would be necessary to clean it from time to time?—I think not. Whether it will ever be necessary to rest them a little I do not know. At present I never do rest them. I do not think anything is gained by it.

2215. For the ordinary amount of purification required by the Rivers Boards the filter alone with the screen for solids would be quite sufficient in your opinion?—I think so, ample.

2216. Without any final sand filter?—Certainly; the sand filter is a drawback.

2217. Have you tried your system upon trade effluents?—I consider that this is a very difficult trade effluent.

2218. Of course it is a very peculiar trade effluent?—It is a peculiar trade effluent, but it is one that has given more trouble in different parts of the country than others.

2219. The soap?—Yes, greasiness.

2220. Albuminoid ammonia in the raw sewage is not very heavy?—In this particular instance it is not, but I have had others in which the ammonias have been very high: in this case it is comparatively small. But 1.6 is not a particularly small amount of albuminoid ammonia; I have known many sewages only in decimals at all.

2221. In wool works, tanneries, fellmongers, it is very high?—Yes.

2222. Do you think it will take a fellmonger's effluent

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and treat it satisfactorily; it would have very high albuminoid ammonia?—I see no objection whatever to the ammonia—none.

2223. (*Colonel Harding.*) Would you be good enough to explain to us a little more in detail the construction of your filter?—Will you kindly look at the section? The section—you notice the bottom of it is a concrete floor, about nine inches of concrete, laid across the floor, with a slope to the outer door from the centre. On the concrete floor you have these side walks built, which are all open single agricultural tiles, a foot thick, with tiles having a slight slope; they are set in cement. On the floor of the filter, at intervals of a yard or two yards—that would vary according to the temperature of the place you are working in—are air flues; in a very cold country you would put them closer together. These flues consist simply of perforated bricks to let the air in and out; they are very cheap and simple. In those a hot water pipe is laid, connected with the boiler house at the side, to get a circulation of hot air through. The body of the filter between the aerated walls is filled in with screened material.

2224. Do these perforated walls come to the top of the filter?—They are just closed at the top with a little cement for convenience of working.

2225. The filter may be considered to be divided into sections by these walls?—I do not quite follow. There is no section in the filters; it is simply enclosed by that wall all the way round.

2226. These walls which you say enclose the pipes?—Oh, those are only flues.

2227. They do not come to the top of the filter?—Oh, dear no.

2228. How high do they rise?—The first nearest the walls—I have there two bricks, nine inches high; then after going in a little way there is a step upward, another brick is put up; that is all.

2229. They are simply on the bottom of the filter?—Yes.

2230. The body of the filter is filled in with material?—Yes.

2231. You spoke to us about cinders and pebbles. Do you use both, or have you tried experiments with them?—I have got one of each. I tried coke, but it did not answer; it gave beautiful results, but after a short time the coke itself sloughed away. I have now got very hard vitrified cinder, which will not slough away; it has behaved very well yet; I hope it will continue to do so. But in case it should not do so, I have pebbles, which are absolutely indestructible, and they answer very well; they do not hold so many microbes as the cinders would do; I do not think I could treat as much sewage on the same area; but as far as the purification goes, I have had very excellent results indeed.

2232. You have got better results with clinker than with pebbles?—No, I will not say that. I got as much as 4·7 of nitrification in a filter with pebble—most extraordinary work.

2233. Do not the smooth surfaces of the pebbles involve the washing away of the bacterial organisms?—If you think of the size of the microbes, and put a pebble under a microscope, you will see it is very rough. It does not house so many microbes—I think that is the weak point—as a piece of clinker, which, of course, is full of large holes, but the roughness of the pebble is quite sufficient to house an immense number.

2234. How do you distribute the crude sewage on to the top of the filter?—That was a very troublesome business. I tried about six kinds of channels, and discarded them. I had a fixed channel; it was a matter of mathematical accuracy to drop from them properly, and it filled with sludge. Then I made a second channel with a V-shaped section, which I had to throw over; that was very expensive. I have now got a channel which is self-adjusting; it fills itself, and when it is full, the weight of the water tips it over, and it rights itself again. My present channel is satisfactory as far as working goes; they are difficult to cast, that is one thing; they are a little too minute to work in. I have designed a simpler, a better one, which any carpenter or blacksmith can put up. I have not got those yet, but those I have at present are perfectly practicable for any filter you like.

2235. These reversing troughs follow the width of the tank?—They go across the tank.

2236. How far apart are they?—They are put a foot to one and a-half feet.

2237. What is the width of the troughs themselves?—Three inches at the top.

2238. When you speak to us about the sewage taking half an hour to go through, do you suggest that it takes half an hour from the time of upsetting the contents of a trough for its contents to pass through the material and to reach the bottom of the filter?—That is it. My cinder filter, which is ten feet high, takes longer. In my eight feet filter of pebbles, in about half an hour from the time it is tipped over, the same sewage will arrive as effluent, and all that time, of course, it is very, very thinly divided, and exposed to the air all the way through, trickling over these pebbles.

2239. The question arises as to any accumulations of solid matters in the body of the filter. You told us that you screened them through a screen with about half-inch openings—the grosser particles; but surely there would pass through such a screen pieces of paper, matches, tea leaves, and stuff that one might describe as grosser solids?—That is so.

2240. Distinct from the matter which goes to form sludge?—Yes.

2241. What becomes of all those in their passage through your filter; are they broken down?—I presume they are; I have never seen them again. Of course, the proportion of them would be very small. I do not say they would not be there in time; if we were working for many years; they could not go very far down.

2242. The smaller solids in suspension, which go to form ordinary sludge, do not come out of the filter?—No; they are entirely disposed of.

2243. Have you been able to judge whether they are really entirely disposed of or whether they accumulate?—I never have any accumulation, and it is rather an interesting thing in the treatment. Sludge is largely composed of carbon, which is dissipated in the form of carbonic acid gas. In the side of the filter, which is, say, 10ft. high, there is a very curious patch across, where the agricultural drain pipes, which no doubt contain a good deal of lime, are frosted with white, showing where the carbonic acid gas has formed carbonate of lime. You can see that very markedly on the filter; you do not find it quite at the top; probably, being heavier, it has fallen down a little towards the end; it sinks. It, I presume, acts completely; there is no more left.

2244. If there were any considerable accumulation you would notice it by a check in the flow of the sewage?—Not only that, but I have an excellent check in the actual working. These pipes are all absolutely open; these pipes that form the sides of the filter are open; they have a small tip, like *that* (*indicating*), and if the sludge was not all disposed of, but collected *here*, and water stayed in the filter, it would immediately show itself in the pipes. So that you can always tell if you are overfeeding or over-working; you can always tell in a very short time by the water.

2245. For what length of time has your filter at Hendon been continuously working?—I think my coke filter worked longer than anything else, from March or April till November, continuously working, and on that I made a number of experiments. I put on very large quantities at times, much more than I intended to work, just to satisfy myself, and there was nothing to show of that until the coke itself began to slough away.

2246. And the filter has been working since November last year? There is a filter actually working?—There are two filters working.

2247. How long have those been working?—Not till about the beginning of the year. I made a number of experiments in the heating, and, of course, every time I changed the heating I had to take out the work. I built them over and over again, about six times, and put them together again. I do not think I got those two filters in work again till March or April.

2248. Would one be right in saying that the filter at Hendon has been working for six months?—Probably not; four or five months. The filter is first constructed, then I have to mature it.

2249. All you can tell us with regard to accumulations is that so far as you have been able to judge there have been no accumulations for four or five months?—That is so. The coke filter worked longer, about eight or nine months; that was seven or eight months, certainly.

2250. Duplicated filtration in your case is not necessary?—Absolutely not necessary.

2251. Eight or ten feet, exposed to these conditions you claim to be sufficient?—Under all ordinary circumstances to be quite sufficient.

2252. (*Dr. Russell.*) Following up Colonel Harding's last questions, I wish to read you a passage from a report by the Medical Officer of Health to the County of

Worcester, dated April 23rd, 1898, which runs as follows: "Colonel Ducat claims that sewage purification of a like high order cannot by any other method be effected so inexpensively as by his process! The tank had in consequence of recent alterations only been running some twenty-four hours when I saw it on January 13th, 1898, so Colonel Ducat very reasonably declined to allow me to take any samples for analysis, but said in a week or two his filter might be in such a state as to permit of my doing so. On making a similar application in the early part of March, 1898, he was unable to afford me the facilities asked for, as his filter was undergoing further alterations." I gather from that passage, and from the replies to Colonel Harding with reference to distributing tanks and other alterations, your system can hardly be said to be a completely worked out system yet; it seems to be in a state of flux?—I think not. I think a solution of all the difficulty has been arrived at. Dr. Fosbrooke came out in January, I think, and I was just making alterations; he came out in March, and I had made another alteration. Of course, it takes some time to get into full working order again. I would not claim it to have been acting nine months, because it takes six weeks or two months before you can put on the full flow of sewage.

2253. Has any independent authority taken samples and had the opportunity of making any analyses?—Dr. Barwise took samples; I am sorry to say I have not brought his analysis with me; it was a very favourable one. He gave 2·5 of nitrification, and said the effluent was fit to go into any stream.

2254. When was that?—That was, I think, shortly after the Congress at Leeds last year.

2255. (*Sir Richard Thorne.*) October?—Somewhere thereabouts, I think. I had another taken a few months ago by Dr. Garstang; he gave me a very favourable analysis. I had a sample taken by Mr. Winter Blyth; he gave me a very favourable analysis.

2256. (*Dr. Russell.*) These are all within the last two or three months?—The last few months, yes.

2257. And this analysis made by Mr. Houston is the most recent?—Yes.

2258. Did he take these samples himself?—I am sorry he did not. I asked him to, but he was unable to do it, and they were taken by my brother, General Ducat, for me.

2259. In the course of this working out of your interesting experiment, did you appeal to a positive analysis? You have spoken of the admirable results of your system as compared with the results of other systems, but have you appealed to chemistry and bacteriology for the criteria of your success?—I have had complete analyses taken, analyses of the ammonias and the oxygen absorbed.

2260. How often were those taken?—They have been taken at very uneven times, when I was making my experiments.

2261. Who carried out the investigations?—Most of them have been taken by Dr. Houston; the others have all been taken by independent gentlemen on their own account. I believe the Thames Conservator frequently takes samples whenever he comes round; the medical officer of health at Hendon takes samples, I believe, constantly, though they have not given them to me.

2262. It would be very important to have those along with the changes, so as to enable us to estimate the real value of the general phrases about the success which you have earned?—I would have brought them, but I was under the impression that the Commission was going to make their own analyses. I only put this forward as a sample of what has been done. Anything taken would naturally have to be checked.

Appendix No. 16.

2263. (*Mr. Cotton.*) Is this an actual plan of the Hendon works, or is it a typical plan?—This is a typical plan; it is on a large scale, 125 feet long; I would not make a filter larger than that.

2264. What is the size of the filter at Hendon?—12 by 15, twenty square yards of filter.

2265. I do not quite understand what you mean by the aerating layer here; it is called aerating layer, and pebbles, and pipes. At the top there is 18 inches of vitrified clinker?—Yes.

2266. Then there comes the aerating layer and one inch of pebbles and pipes?—The meaning of that is that beside one of these pipes—I lay agricultural drain pipes from side to side right across; between the pipe *here* and the pipe *there* I fill in with *this*. That, of course, can be seen at Hendon, where you can see completely through the pipes.

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2267. At what level is the sewage received; there is a plan here, but no section of the main sewer?—That is only a typical plan. At Hendon I am compelled to gravitate the sewage on an eight feet filter; a little lower down it could be on a 10 feet filter.

2268. Are the tipping channels in use at Hendon?—They are.

2269. What are they made of?—Iron.

2270. How are they suspended?—They are supported on pivots, and they rock on these rocking pivots. Those I have at Hendon are rolled, but they are not very satisfactory, because they are not rolled true. I am going to have them cast, because I think they would be much more easily worked.

2271. What is the exact action and operation of the hot-water pipes; I do not quite see that from the plan?—The hot-water pipe lies at the bottom of these flues which are formed on the bed of the filter. The cold air is drawn in from both ends, and it, of course, follows that as the hot-water pipe gets heated, it tends to rise through the walls in the perforation of the bricks and gets into the filter. It has been very difficult to get that distribution of hot air. I do not want to heat the filter; that is no use to me.

2272. Are the hot-water pipes at Hendon?—Yes.

2272.* (*Professor Foster.*) I do not quite understand your filter yet. May I take you to this section showing the filtering material?—Yes.

2273. The sewage is tipped on to the top?—Yes.

2274. Then it passes through your layer of vitrified clinker?—Yes.

2275. Then it goes through your aerating layer?—Yes.

2276. Do I understand that the air is brought in through the pipes? How does the air get access to the material in your aerating layer?—Through the perforated sides of the wall.

2277. Through the perforated sides of the wall?—Opposite one of these pipes which form the wall I put a line of pipes in, butt-jointed agricultural pipes, resting on the material, so that you can see from one side of the filter to the other. Those pipes are put about a foot apart, and between those pipes I put the material, about one inch, so that the air can get through the joints of the pipes.

2278. Through the joints of the pipes?—Yes.

2279. And so through the pebbles?—And so through the pebbles.

2280. But then the fluid goes through the pebbles and through the joints of the pipes into the pipes?—Well, it does not get into the pipes practically; the pipes are damp, that is all; it is never submerged; it merely trickles through; nothing ever stands there; you can see through the filter; you can see the pipes, they are just damp.

2281. Then the material having taken up air from that aerating layer passes through another layer of vitrified clinker?—Yes.

2282. And then it gets a fresh supply of air at the net layer, and so on?—Yes. Then in addition to that the sides are completely aerated.

2283. So that there is a liberal access of air through the whole depth?—Through the whole depth as well as through the aerating layers.

2284. And the fluid can get out through the sides?—It could if it stood in the filter.

2285. What amount of escape is there from the sides?—It is all open.

2286. But I mean what amount of fluid does actually escape?—None.

2287. The pipes slant?—Merely tip inwards, so that it would have to stand about two inches deep before it would run out at all.

2288. How do you determine the time it takes the sewage to get through?—I have tested it with dry filters.

2289. That is the time through an empty filter, not the time through a full filter?—When I begin to mature the filter I turn the sewage on to the filter, the dry filter, for one hour the full charge I am going to give it ultimately, and then I stop for an hour. Then I turn it on for a second hour; then I stop for an hour. I do that for about ten days or a fortnight. So that after any time, after

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the material has been once damped, after it has rested an hour, it is fairly empty; then you can see how long it takes coming through again.

2290. Your rate would be that at which it goes through an empty filter, not through a full filter?—It never stands in the filter; it is always the same motion going on. The only difference between a new filter and one that has been working would be that the new filter would absorb liquid.

2291. Supposing while your filter was working you put the material on the top of your filter, you say it takes a certain time to come through; how do you know it takes a certain time to come through?—I have tested it with what is coming through.

2292. You have got a continual flow going through your filter?—Yes.

2293. How do you know when you put a particular sewage on the top the time at which that particular sewage gets to the bottom?—When I am maturing a filter at first, when you first turn it on to the new material the material absorbs a certain amount, but after it is once saturated then you see stuff going on and coming out of the bottom. Then I turn it off for an hour for resting to get mature; I then turn it on and take the time by my watch, the effluent channel then not being running. I watch the channel and see when it begins to run again. That is the only test I have got.

2295. That is the time it takes to go through an empty filter. Are you sure that that is the rate at which it goes through a filter when it is full from top to bottom?—I do not suppose it is mathmatically correct, but it is as near as one can get it.

2296. (*Professor Ramsay.*) Would it not help to put in some dye stuff at the top?—I am not sure that the dye stuff would come out again. There is neither smell nor colour.

2297. (*Professor Foster.*) You only infer the actual rate through your working filter from the time it takes to go through when you are filling it?—If you can show me any way by which I could do it more correctly I should be very pleased. I do not mean to do it by inference; I do it as far as I can by practical testing.

2298. (*Mr. Killick.*) Aniline dye would probably show it?—Possibly.

2299. (*Professor Foster.*) I think you said the pebbles did not hold so many microbes. How do you know they do not?—By the amount of work they can do; that is entirely inference, I have never had them examined.

2300. What you really mean is that the pebbles——?—I merely infer.

2301. You merely infer that they do not?—Because they do not do so much work.

2302. But you said the pebbles did not hold so many microbes?—That is my impression.

2303. Your inference; you have not made any examinations?—No, I have not.

2304. I think in your statement you said that you choose a certain size of fragments?—Yes.

2305. Is that as a result of a number of comparative trials of different sizes?—A large number.

2306. You have come to the conclusion that that is the optimum size?—I think those are the best. I first of all began with very much larger material, three inches in size, but I was only filling up my filter and getting no results. I worked it down until I found this was best. You must have a certain amount of coarseness on the top, but as little as possible. I have arrived at this from a number of experiments.

2307. I understood you to say, I think, in answer to Mr. Killick, that there is no accumulation of material on the top of your filter?—Nothing to speak of.

2308. And the pieces of paper, or any other refuse, that passes your screen is not delayed on the top, but disappears in the course of time?—Yes.

2309. Have you studied bacteriology yourself much?—No; I do not profess to be a bacteriologist.

2310. When you speak of anaërobic and aërobic you are using the terms only in a general way?—Quite so.

2311. Your contention being that for the ultimate solution of even the solid matter, which is contained in the sewage after it has passed your screen, a condition involving the absence of oxygen, and, therefore, probably the action of anaërobic organisms is not necessary?—Is not necessary.

2312. The whole business can be done by organisms (or whatever is done is done by things) in the presence of oxygen and their work is facilitated by the presence of oxygen?—That is my impression.

2313. So that it is not necessary that there should be beyond such action as may have taken place in the sewage before it reaches your filter—there is no necessity for any action of the so-called anaerobic organisms?—I believe none.

2314. The bacterial analysis which you have handed in, it is only one analysis?—That is so.

2315. Have you more than that one?—I have only one complete bacterial analysis.

2316. Only one?—Only one.

2317. I observe that in this one, although there was no bacterim coli, the enteritidis did pass through?—But with an immense reduction in number.

2318. But it passed?—Yes, it passed.

2319. So that that filtrate could not be stated to be absolutely free from dangerous organisms, because the enteritidis is supposed to be a dangerous organism?—No doubt, but I believe very few waters are absolutely free. I do not profess to turn this into absolute drinking water.

2320. Only two examinations bacterially have been made?—That is all.

2321. And none at all of what is going on in your filter; for instance, of the fluid which may be obtained from these aerating pipes have any cultures been made from the moisture?—None comes out there.

2322. They are moist?—I have never taken samples from those to be analysed from the different levels in the filters, and as far as I am concerned practically, it would not interest me. They are incomplete filtrates, and, therefore, they would be of no interest to me. Of course, they could be got, but they would be very difficult to get, because no water lodges there.

2323. They are moist, so that you could obtain some fluid from them?—You could obtain a very small quantity of fluid from them; it could be done.

2324. (*Professor Ramsay.*) Does the water run down over the filtering material in small channels, so as to moisten the outside, or does it drip from the pipes, or does it flow? I have difficulty in realising the rate at which the sewage passes through the filter?—It certainly does not flow.

2325. It drips, I presume?—I presume it spreads over, because you can find it, though the channel tips—I have got my channels 15 inches apart now—and if you watch them throw they do not throw over the whole. If you take a bit that is dry and dig a little hole, you will not go far down before you find it just as much damp as the rest. So that I presume it goes over the whole filter.

2326. Have you actually tried heating with the air, or is this only an idea of what ought to be done?—I have tried it very much. I tried heating the air; I found I could not do it at all, I could not manage it. Now I heat the air over these pipes, and, of course, there is no question about that, I can see them heated; cold air goes in, strikes on the pipes; you can test the flow of air into it.

2327. Because the amount of heat one can give air is very small, and the number of degrees of temperature though it would raise the water, would be exceedingly small?—I am not trying to do that at all. That is the thing, and that is very much misunderstood. People think it must be a frightfully costly process to raise the temperature of the filter. I do not do that. The sewage comes in hot enough for all practical purposes. I want to supply that with oxygen from the air which is not cold; if cold strikes on the filter it would destroy microbic action for the time being.

2328. Have you any data to show as to the purity of the effluent, that in any submerged filter from which air is excluded, it will be found that when the valve is first opened the purity of the effluent is very much less, as much as 50 per cent. less, than it will be when the filter is nearly empty?—Yes, I have seen it myself, I have had it from a number of people who have been in charge of works, and I have watched it with great care. Mr. Law told me that himself; he gave me the percentage, but I think his percentage was not so high as it might

be. I have seen the sewage at Hendon and other works twice filtered, and the second filtrate, when the valve was first opened, you could smell from *there*. I have seen it at Sutton; I have tested it in a number of places; when the valve is first opened there is almost always a smell, not always.

2329. Then about two-thirds of the way down the page you say again that all pretence at regular aeration has been thrown aside, but there are many cases surely in which regular aeration is kept up?—Yes, I only say during that time, during the time the submerged filters are working as a continuous flow, they are filled, and they are overflowing, and they continue so. While that is going on, while the filter is actually submerged, there can be no aeration. You see, in that process the intention was to empty the filter entirely, to keep it empty for three hours for aeration. If you do not empty the filter, but keep it running, full, there it no aeration.

2330. To be sure. On page 4 also, about two-thirds of the way down where you give the items of expenditure, you reckon the masonry, and so on, £1 10s., but that is a capital charge, is it not?—Yes.

2331. Along with the distributing channels and the rest, but the heating is a current expense, is it not?—The fuel is.

2332. You say 15s.?—That is the construction.

2333. Not the actual heating?—No, the construction—15s. per square yard.

2334. We ought to say "heating apparatus"?—That would be more correct.

2335. (*Professor Foster.*) At the end of page 2 you make a statement that where the effluent has been discharged into the sea a depth of filter of five feet would do; then you say that a filter and plant would be required for other circumstances of twelve or fifteen feet deep. What are the exact data upon which you base those opinions?—Well, it would be difficult to get accurate data no doubt; that is a general statement.

2336. You have no means of testing the changes which are taking place at various depths in your filter?—No.

2337. It is only a pious opinion, in fact?—That is all. The solids are all disposed of before the five feet; I know that much.

2338. What is the evidence of that?—It is difficult to give evidence of that, too. No more signs of the carbonic acid gas are traceable. I ought not to have said so; it was not accurate; I have no actual proof of it.

2339. (*Sir Richard Thorne.*) You were saying that you judged that the pebbles did not hold so many bacteria as the cinders by the character of the effluent?—No, sir, not by the character of the effluent, but by the quantity of work I could do. The character of the effluent has been quite as good

2340. But does not the work you can do mean the character of the effluent?—The quantity I can do, not the quality.

2341. Well now, you say there have been two bacterial examinations by Dr. Houston. Was one of those made with cinders and the other with pebbles?—The first was made with coke, and this one is from the cinders.

2342. *(Professor Foster.)* The vitrified clinker?—Yes.

2343. (*Sir Richard Thorne.*) You have none with the pebbles?—I have none from pebbles, sir.

2344. There is one in which the bacillus enteritidis passed through, what was that an examination with?—That is from the clinker filter, the filter now working at Hendon.

2345. Have you ever had any bacterial or chemical examinations in order to contrast the results in drought and following on rainfall?—No, I do not think I have; they have been taken promiscuously.

2346. Relying as you do on bacteria, do you run any danger in the case of heavy rainfall, since you take all the rain to your filters, of having the bacteria washed out from them?—I do not think so when you come to think of the size of the channel that brings it in, about two inches in diameter. Mine is not so much, about 1½ inch: I spread them over a flow of 20 square yards. If you reduce the velocity of that you will find it is practically scarcely appreciable.

2347. (*Professor Foster.*) You have never had the effluent examined during a rain storm?—No, I have not.

2348. (*Sir Richard Thorne.*) When you were experimenting with coke, did you find that the finer material at the bottom of your filter tended to break up and become disintegrated at all?—That is why I rejected the coke filter.

2349. I suppose the sewage would form channels through that?—No, it caked, and the sewage did not go through it.

2350. That was the reason you abandoned it?—That was the reason I abandoned it.

2351. When you are preparing the filter, you tell us it takes about six weeks or two months before it is in proper working order?—Yes.

2352. If you had to change the material at intervals of, say, ten or twelve months, you would practically have to abandon one filter for a period of two months?—Yes. Of course, if that was found necessary in practice, you would have to allow a certain percentage of extra filters for that.

2353. How do you propose to get the necessary elevation in most cases for delivering the sewage at a height of from 8 to 11 feet, according to the height at which you must build your filter?—It comes to this: In an ordinary filter, which is, say, 3ft. 6in. or 4ft. deep, you must have that amount of head. If that could not be done it would have to be pumped.

2354. The sewage or the effluent?—I should pump the sewage.

2355. That would necessarily add to the expense where you had to do that?—Of course.

2356. Can you tell me at what point of the sewer you take the sewage that you deliver on to your filter; do you take it at the surface of the sewage that is flowing along, or from where?—At Hendon, do you mean?

2357. Yes?—I take it there at the bottom of the channel.

2358. Why do you choose the bottom?—Because it has such a varying head. At times it is a little only, a mere film, and in order to get my filter to work then I have a little weir across, which accounts for my sewage being worse than normal.

2359. Is there much difference in the constitution of sewage, according as you take it, at one depth or another?—Yes.

2360. Which is the worst?—Below.

2361. You profess to take the worst?—I have the worst.

2362. At what external temperature of the atmosphere do you imagine you would have to put on your heating power?—I have very good results down as low as 40° Fahr.

2363. Below 40, you think?—I should like to have heat.

2364. Have you at all estimated how many weeks in the year, taking an average of years, that would mean you have to apply heating power?—That would vary very much according to the locality. I have always taken it at about half the year; I do not suppose that in most cases it would come to as much.

2365. Your great point is this, as I understand it:—You have an automatic and continuous aeration at almost every level in the height of the 8ft. or 12ft. of filter to which you expose the sewage?—That is so.

2366. And on that you rely for the effects produced?—Yes. I have absolute aeration all over, no matter what the height may be.

2367. (*Professor Ramsay.*) Is your filter protected?—It is protected for winter, yes.

2368. I mean patented?—Yes.

2369. (*Chairman.*) How long is it since you put up your first filter?—January last year.

2370. That was when you had coke?—Yes.

2371. And you found that coke choked?—Yes, it became pulverised; it disintegrated and formed a solid cake.

2372. Have you any way of preventing the effluent that goes through the filter forming channels for itself?—Do you mean through the filtering material?

2373. There is a flow through your filter, and it is natural it should make a channel for itself unless you have any means of preventing it doing so?—I have riddled the material so that I have no dust in it. I am very careful to put clean material into the filter; I crush the cinders

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by machinery and riddle them through a riddle and reject all the fine stuff below ½in., so that there is no tendency after that for the sewage to form little rivulets for itself. It spreads all over from the action of the tipping channels, and being on this surface it finds its way through the first gap which would be over individual atoms of the filtering material.

2374. How long was it before you found the coke choked?—I should think about four or five months.

2375. And you do not find the clinkers choke?—No, not at present.

2376. How long have you employed them?—Only since March or April. I do not know how it will stand. Of course they are very different materials. Coke is very soft stuff compared with vitrified cinder.

2377. If we sent anyone down to Hendon would you allow him access to take samples or make an examination?—Certainly, whenever you choose.

2378. (*Sir Richard Thorne.*) May I ask you whether these pipes that you put in at four different intervals in the height of the filter consist of several layers?—No, a single layer.

2379. And are they practically continuous across the whole of the surface area at the points they are laid?—No, they go through about one foot apart, at about foot intervals right across the whole filter from end to end, so that you can see through them, and between the pipes I lay in the material.

2380. I was only wondering whether this arrangement would prevent anything like the formation of a channel, but they would not if they are placed like that?—No, they would not.

2381. (*Colonel Harding.*) If any members of the Commission wished to go to Hendon this filter is now continuously at work?—Yes.

2382. There would be no difficulty?—I should be glad to show the Commission if they would like to go; I should be glad to be there, and you are welcome to go at any time. But if I could know when you were going I should be very pleased to be there and explain all the little details and the reasons of them.

NINTH DAY.

Thursday, 20th October, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

Mr. W. E. ADENEY, D.Sc., F.I.C., Royal University, Dublin, called; and Examined.

Mr. W. E. Adeney, D.Sc., F.I.C. 20 Oct. 1898.

2383. (*Chairman.*) You are Dr. Adeney, of the Royal University, Dublin?—Yes, my lord.

2384. And you kindly hand in a paper which shows what your system is called, what your system does, what are the principles upon which your system is based, what results you have obtained by experiment, and what conclusions you have drawn from your experiments, and the methods you would employ for increasing the supply of oxygen when you require it, the different rates at which fermentation goes on, and some particulars of the works at Dundrum, Chapelizod, and Northallerton?—Yes.

The distinctive features of this process are—(1) It effects the purification of the *suspended matters*, as well as those in solution, by aërobic fermentation; and (2) it ensures the necessary condition of oxygen supply by the employment of certain forms of combined oxygen—viz., crude manganese compounds for the fermentation of the suspended matters, and nitrate of soda for that of the dissolved organic matters in the sewage.

SCIENTIFIC PRINCIPLES UPON WHICH THE SYSTEM IS BASED.

The principles, upon which the system has been based, have been established by an extended experimental study, in the laboratory, of the chemical changes which the organic matters in sewage undergo under the influence of the bacteria, common to such liquids, when they are subjected to aërobic conditions. The results of these researches have been published in the Scientific Transactions of the Royal Dublin Society under the title "The Course and Nature of Fermentative Changes in Natural and Polluted Waters, and in Artificial Solutions, as Indicated by the Composition of the Dissolved Gases." Parts I., II., III., and IV. (see vols. 5 and 6, 1895 and 1897). Abridgments of these papers have also been published in the Transactions of the Institution of Civil Engineers of Ireland, 1896 and 1898, and reprinted in *Engineering*, Vol. LXI., pp. 728-730, and 762-764, and Vol. LXVI., pp. 277-278.

It has been found from these researches that the purification of the organic matters, both suspended and dissolved, in sewage by the bacteria common to nature (under aërobic conditions) partakes of the nature of a slow combustion, about 90 per cent. of the organic carbon being oxidized to carbon dioxide, the other organic constituents being converted into water and ammonia, small quantities of organic colouring matters being also formed.

It has also been found that the oxidation of ammonia to nitrous and nitric acids does not commence until the whole of the organic matters have been first completely fermented.

The following experimental results may be quoted in illustration of these changes. The sewage employed for the experiments was an average sample of the daily flow from the Richmond Main Drainage Works, near London. It was filtered before use to separate the suspended matter (Trans. R.D.S., Vol. V., pp. 568-575). Under the columns headed I. and II. are given the results of analysis, before and after, fermentation respectively; the fermentative products are given along the horizontal lines headed "differences."

Mr. W. E. Adeney, D.Sc., F.I.C.

20 Oct. 1893.

TABLE I.—EXPERIMENTS WITH SEWAGE AND TAP WATER.

Commenced June 24th, 1893.

Gases Expressed as Volumes at N.T.P., and Nitrogen Compounds as parts by Weight, per 1,000 Volumes of Solution.

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_3 I.	N as N_2O_3 II.	Remarks.
1893												
July 25	1 in 10	23·35	29·44	6·42	0·00	13·41	14·83†	0·0045	0·0047	0·0009	0·00	Solution very offensive after fermentation.
	Differences	+6·09*		— 6·42		...		+0·0002		— 0·00009		
July 26	1 in 20	14·12	19·78	6·44	0·18	13·41	13·49	0·00225	0·0025	0·00009	0·00	Solution free from odour after fermentation.
	Differences	+5·57		— 6·26		...		+0·00025		— 0·00009		
July 26	1 in 40‡	9·64	12·45	6·46	3·16	13·41	13·49	0·001125	0·00115	0·0001	0·0001	Ditto.
	Differences	+2·81		— 3·30		...		+0·000025		0·0		
Sept. 1	1 in 80	7·36	9·17	6·46	2·12	13·41	13·34	0·00056	0·00	0·0001	0·0008	Ditto.
	Differences	+1·81		— 4·34		...		— 0·00056		+0·0007		

* This volume includes traces of SH_2.
† This volume includes N, CH_4, and H, disengaged during fermentation, but they were not separately determined.
‡ The remainder of this solution was, immediately after examination, re-aërated, analysed, and set aside to ferment till September 1st, when it was re-examined, with the following results :—

1893 Sept.	...	11·31	11·99	5·78	1·44	12·96	12·99	0·00115	0·00	0·0001	0·0017	...
	Differences	+0·68		—4·34		...		—0·00115		+0·0016		

It will be observed the sewage was diluted with gradually increasing proportions of tap-water, and that the atmospheric oxygen, required for the fermentative process, was derived from the dissolved oxygen in the mixtures or solutions so formed. During an experiment the solution was kept out of all contact with the air, and preserved in a bottle, which, in its turn, was kept in such a way that gases could neither gain access to, nor to escape from, it.

The experiment with the first solution illustrates the results obtainable when the free oxygen dissolved in the solution was insufficient for the complete aërobic fermentation of the organic matters present in it.

The significant results to be noted under these conditions are—(1) A partial anaërobic fermentation, accompanied by bodies emitting offensive odours; (2) only about half the organic matters present in the solution were oxidized (for evidence of this compare results with those of the two succeeding experiments).

The results recorded for the second experiment show that the dissolved oxygen was just sufficient for the fermentation of all the organic matters present.

The significant results are—(1) The complete absence of products of anaërobic fermentation; (2) the complete oxidation of the organic matters, with the formation of carbonic acid, ammonia, and a small quantity of organic colouring matter.

Two experiments were made with the third mixture. At the conclusion of the first experiment, the organic matters were completely fermented, while during the second experiment the ammonia was completely fermented. It is important to note during this last experiment that only a small volume of carbonic acid was formed in proportion to the quantity of ammonia fermented. This CO_2 was derived from the colouring organic matters formed during the fermentation of the organic matters in the first experiment with the solution.

The fact that these colouring matters do suffer fermentation along with ammonia is well illustrated by the experiments recorded in the following table. The experiments were made with an average sample of effluent from one of the filter beds at the Richmond works already referred to :—

TABLE II.—EXPERIMENTS WITH SEWAGE WHICH HAS BEEN FILTERED THROUGH GRAVEL FILTER-BEDS AND TAP WATER.

Commenced June 24th, 1893.

Gases Expressed as Volumes at N. T. P., and Nitrogen Compounds as Parts by Weight, per 1,000 Volumes of Solution.

Date of conclusion of Experiment.	Solution.	CO_2 I.	CO_2 II.	O_2 I.	O_2 II.	N_2 I.	N_2 II.	N as NH_3 I.	N as NH_3 II.	N as N_2O_3 I.	N as N_2O_3 II.	N as N_2O_3 I.	N as N_2O_3 II.
1893 July 18	1 in 2	77·50	83·85	6·38	0·00	13·58	13·70	0·0085	0·0075	0·0018	0·0016	0·003	0·0045
	Differences.	+6·35		−6·38		...		−0·001		−0·0002		+0·0015	
	1 in 4	41·29	44·00	6·43	0·00	13·58	13·54	0·00425	0·0030	0·0009	0·00003	0·00155	0·0028
	Differences.	+2·71		−6·43		...		−0·00125		−0·00087		+0·00125	
July 20	1 in 8	23·18	24·80	6·45	0·00	13·58	13·43	0·00213	0·0005	0·00045	0·00	0·000825	0·0028
	Differences.	+1·62		−6·45		...		−0·0016		−0·00045		+0·00199	
July 24	1 in 16	14·12	15·11	6·46	3·41	13·58	13·54	0·00107	0·00025	0·000225	0·00	0·000402	0·0016
	Differences.	+0·99		−3·05		...		−0·000822		−0·00025		+0·001	

REMARK.—All the solutions were quite free from odour after fermentation.

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The organic matters in the sample experimented with had been completely fermented by the process of filtration at the Richmond works, so that we have illustrated in the above table the fermentation of the organic colouring matters formed during that process, and of the ammonia.

It will be observed that decided volumes of carbonic acid were formed during each experiment, and these were derived from the said colouring matters; decided quantities of ammonia were also at the same time fermented.

On examining a little more closely the results recorded in the above two tables, it will be seen that the bacteria behaved in all the solutions, where aërobic conditions were complete, as practically constant chemical factors, and that (1) the product—carbonic acid—of the fermentation of the organic matters, and (2) the final product—nitric acid—of the fermentation of ammonia, and that, also, the volumes of oxygen consumed during each stage, are directly proportional to the quantity of polluting matters originally present in the solutions.

These relationships will be more easily seen if we multiply each set of differences recorded in the tables to render them comparable with the undiluted samples from which they were prepared, and with one another, as follows:—

From Table I.

Solution.	Multiplier.	1 CO_2	2 N as NH_3	3 N as N_2O_5	4 Vol. of O_2 absorbed.
1 in 10 - -	10	+ 61	+ 0·002	0·0	64
1 in 20 - -	20	+ 111	+ 0·005	0·0	123
1 in 40 - - (1st stage)	40	+ 112	+ 0·001	0·0	132
1 in 40 - - (2nd stage)	40	+ 27	− 0·046	+ 0·064	174
1 in 80 - -	80	+ 145	− 0·045	+ 0·056	347

From Table II.

Solution.	Multiplier.	1 CO_2	2 N as N_2O_3 oxidised to N_2O_5	3 N as NH_3 oxidised to N_2O_4	4 Vol. of O_2 absorbed.
1/2	2	12·7	0·0004	0·0026	12·8
1/4	4	10·8	0·00348	0·0015	25·7
1/8	8	13·0	0·0036	0·0122	51·0
1/16	16	15·8	0·0036	0·0124	48·2

The experimental results which I have quoted are sufficient, perhaps, to illustrate the character of the fermentative changes which bacteria bring about in effecting the purification of sewage under aërobic conditions. They are not, I should state, isolated results, but are, on the contrary, borne out in the conclusions to which they lead by a very large number of other experiments, the results of which will be found recorded in the papers already referred to. I have also a considerable volume of experimental evidence, all supporting the same conclusions, in preparation for publication.

We may take it then that the purification of sewage by aërobic bacterial fermentation is, so far as the chemistry of the fermentative changes is concerned, a question of extreme simplicity, and that in the problem of the purification of sewage on the large scale we have only two conditions of first importance to be secured for successful work. They are—(1) a very large and continuous growth of bacteria, and (2) a constant and adequate supply of oxygen for the same.

If the supply of oxygen be wholly drawn from the atmosphere, there is only one known successful method of securing the above two conditions. I refer to the process of natural or artificial filtration in which the filtering material exposes large surfaces upon which the bacteria may grow and accumulate, and the interstices between the filtering material provides store spaces for the atmosphere.

Other methods may, however, be with advantage employed, if other available sources of oxygen, in certain forms of combination, be employed *in addition* to that of the atmosphere for furnishing the necessary supply of that element to bacteria. Thus the insoluble higher oxides of manganese may be employed for furnishing the necessary oxygen supply for the complete aërobic fermentation of the *suspended* organic matters of sewage.

Again, small quantities of nitrate of soda may be employed in company with the atmosphere to furnish the necessary oxygen supply for the complete aërobic fermentation of the dissolved organic matters of sewage.

I will first consider the chemical behaviour of the higher oxides of manganese when mixed with the suspended matters of sewage in the form of ordinary sludge.

Suspended Matters in Sewage.

Peroxide of Manganese.

A Source of Oxygen Supply for Aërobic Fermentation.

The fact that the higher oxides of manganese, when mixed with sewage solid matters, prevent the same from becoming offensive has been observed by the late Mr. MacDonald Graham and by Professor W. N. Hartley, F.R.S. The former regarded their influence as dependent in some unexplained way upon the presence of phosphorus compounds; the latter observer has suggested that their influence was probably due to an oxidizing action in the presence of micro-organisms. The first direct experiments on the subject are recorded in two papers, one of which I have already referred to (Trans., R. D. S., vol. vi., 1897), the other entitled "The Reduction of Manganese Peroxide in Sewage," and published in the Scientific Proceedings of the R. D. S., vol. viii., p. 247, 1894.

In these papers it is shown that when compounds of manganese are employed for clarifying the sewage, sludges are obtained, which, when drained and kept in heaps, undergo slow aërobic bacterial fermentation resulting, in the presence of a sufficient quantity of peroxide of manganese, in the complete fermentation of the solid organic matters in the sludge, and in the reduction and conversion of an equivalent quantity of peroxide of manganese to manganous carbonate.

The products of the fermentation of the organic matters under these circumstances are precisely similar to those which, as shown by the above tables, are obtained by the aërobic fermentation of *dissolved* organic matters.

The organic colouring matters, which are found in the sludges after this process of fermentation has been completed, have been found to amount to upwards of 8 per cent., calculated on air-dried samples of the sludge. On careful examination they have been discovered to be exactly similar in chemical, fermentative, and physical properties to the "humus" of ordinary cultivated soil.

The chemical changes which the peroxide undergoes during this process of fermentation, may be represented by the following equations:—

$$(1)\quad 2MnO_2 = 2MnO + O_2$$
$$(2)\quad C + O_2 = CO_2$$
$$(3)\quad MnO + CO_2 = MnCO_3$$

These reactions will be found on calculation to give rise to a considerable quantity of heat, and constitute, therefore, a source of considerable energy to the organisms.

Dissolved Organic Matters in Sewage.

Nitrate of Soda a Source of Oxygen Supply for Aërobic Bacterial Fermentation.

It is known and now generally accepted that the principal chemical function that nitrates discharge in any bacterial fermentation they take part in, is to supply oxygen to the bacteria, and that in doing so they undergo a decomposition, according to the following equation:—

$$4NaNO_3 = 2N_2 + 2Na_2O + 5O_2$$

As an example of their power of supporting aërobic fermentation, I may quote an experiment with a sample of crude sewage, conducted similarly to the experiments described in the above tables. The suspended matters of the sewage were separated by filtration through paper, it was then mixed with a small quantity of nitrate of soda, and preserved completely out of all contact with the air for two months. The following figures were obtained on analysis before and after keeping:—

	CO_2	O_2	N_2	N as NH_3
Before -	80·87	3·8	17·57	0·06
After -	315·0	0	24·29	0·08
	+224·13	−3·8	+6·72	+0·02

I may add that a similar volume of the same sample of sewage when fermented in the presence of atmospheric oxygen, yielded 245 volumes of carbonic acid, and consumed 275 volumes of oxygen.

The importance, however, of this function of nitrate of soda, so far as the treatment of sewage on the large scale is concerned, depends upon the fact that when present in small quantity in sewage, they do not suffer appreciable change, except in the entire absence of dissolved atmospheric oxygen. In other words, nitrates do not discharge their function wherever atmospheric oxygen can penetrate into the mass of the fermenting sewage.

This fact is admirably illustrated by the results of the two following experiments with two samples of slightly polluted river water:—

	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5
1	116·05	5·99	15·08	0·0044	0·00024	0·00992
	123·68	0	17·17	0·005	0	0·009
	+7·63	−5·99	+2·09	+0·0006	−0·00024	−0·00092
2	116·39	7·38	15·58	0·0013	0·00018	0·01084
	119·71	0	15·63	0·0006	0·00016	0·01174
	+3·22	−7·38	—	−0·0007	−0·00002	+0·0009

These two experiments were carried out similarly to those already referred to.

From the first analysis it is evident all the dissolved oxygen was consumed, and a reduction of a small quantity of nitrate took place, since some gaseous nitrogen was formed and the nitrates were present in less quantity after the fermentation than before. In the second experiment no reduction of nitrate took place, although it is evident from the volumes of carbonic acid formed and of oxygen consumed a fermentation of organic matter occurred.

To sum up generally the facts which have been experimentally determined as to the fermentative changes which may occur in a sewage, we now know that aërobic fermentation will take place in it, to the exclusion of anaërobic fermentation, so long as the supply of oxygen is present in it, either in the free form as dissolved oxygen, or in the combined form as nitrates, and we know also that if both forms be present, the latter will not be affected by the fermentation till the former has been all consumed.

Relative Rates at which the Fermentative Changes Proceed under Different Conditions of Oxygen Supply.

We may infer from the foregoing what has been found as an experimental fact in reference to the factor time, that the conditions under which bacteria effect chemical changes most rapidly is that in which oxygen is supplied to them in the free atmospheric form, next in point of time is that in which the oxygen is supplied in the combined form of nitrate, and next in the combined form as manganese peroxide.

Under anaërobic conditions chemical change is effected extremely slowly.

It is well to bear in mind that the discovered influence of the *form* in which oxygen is supplied on the velocity of bacterial fermentative change is precisely what would have been anticipated from thermo-chemical principles. This is of importance, since the question of the purification of the sewage of a town is really a question of making provision for adequate chemical energy, the data for the exact calculation for which provision can now be accurately ascertained by suitable methods of analysis.

Application of Scientific Principles on the large scale by the Oxygen Sewage Purification System.

The scientific principles which I have briefly described have been applied to the purification of sewage on the large scale by Mr. W. Kaye Parry, M.A., C.E., of Dublin, with the assistance of Mr. James Carson, C.E., of Dublin, and of Mr. T. A. Shegog, A.R.C.Sc.I., F.I.C., director of Technical Instruction under the Monmouthshire County Council.

By the united efforts of these gentlemen it has been demonstrated that it is quite possible to successfully treat sewage on the large scale upon these principles.

The Oxygen Sewage Purification Company have erected, under the direction of Mr. Shegog, a factory at Newport, Monmouthshire, for the manufacture of a sewage precipitant from flue dusts he obtained from ferro-manganese furnaces, and from certain manganiferous ores.

This precipitant is termed "oxanite." It consists of a crude sulphate of manganese mixed with the higher oxides of that element. It can be sold in small lots at 45s. per ton at works.

With reference to use of nitrate of soda, it has been found that one half to two grains per gallon is quite sufficient to afford a most satisfactory effluent from any ordinary town sewage, an effluent in which, when kept in corked bottles, aërobic fermentation is rapidly completed, and in which no putrefactive fermentation takes place.

The nitrate of soda is added to the sewage after the latter has been clarified, and as it passes from the precipitation tanks to what are termed biological tanks. These tanks are worked continuously to ensure a constant presence of a large and active bacterial growth within its contents. Open networks of porous material should also be built in these biological tanks, to provide ample surface upon which bacteria may grow and accumulate.

Works which have been erected for the application of the Oxygen Process.

In the Appendix attached to this statement, and which has been drawn up by Mr. Parry, drawings and statements will be found as to cost of erection of the works which he has designed for the installation of the process at the Lunatic Asylum, Dundrum, co. Dublin, at the Police Barracks, Chapelizod, co. Dublin, and at North-allerton, Yorkshire.

Mr. Parry has also given some salient particulars as to the method of operating these works.

For further details, or for particulars as to the application of the process to large volumes of sewage, it would be advisable, I think, to make application directly to Mr. Parry.

Efficiency of Treatment.

Dundrum Works.

The works at Dundrum have been in operation at Dundrum for seven years, and I can speak from personal observation of what the process has effected in that locality.

The effluent from the works discharges into an open ditch which receives the land drainage and cess-pit overflows, and also, I am informed, other sewage matters, from some neighbouring residences and houses.

The volume of water flowing through this ditch is, during winter seasons, generally about four to six times that of the effluent discharged into it from the asylum.

This ditch opens out into an ornamental pond some four hundred yards below the outfall of the asylum. At the time when the oxygen system was first installed, this pond was in a most foul state, the bottom being covered with a black stinking mud, three or four feet deep, and consisting of sewage matters, decaying vegetable matters, and clay.

The pond was, in fact, so foul that the top of this mud was covered with a red fungoid growth, so characteristic of anaërobic fermentation, when exposed to strong daylight. The state of this pond has been entirely changed by the operation of the oxygen process. I made a careful inspection of the ditch and pond last April in company with Mr. Parry and others. We found that the mud on the bottom of the pond was quite free from offensive odour and of a clay-like colour to within an inch or two of the hard bottom of the pond; the surface of the mud was moreover here and there covered with a green growth. The water was at the same time quite sweet and clear. There is no doubt in my mind that this state of things has been entirely brought about by the influence of the nitrate of soda which is discharged into the ditch with effluent, in promoting aërobic and preventing anaërobic fermentation.

There was also evidence to show that the higher oxides of manganese in the "oxanite" employed for precipitation was exercising a beneficial influence in the ditch as well as in the precipitation tanks.

Particles of these oxides had escaped with the effluent, and had been deposited along the bottom of the ditch, forming a thin layer of clay-like mud. There can be little doubt that this layer of mud, mixed as it certainly was with aërobic organisms, and in the presence of atmospheric oxygen and nitrates dissolved in the waters flowing over it, exercises a most rapid purifying influence on those waters.

For precipitation purposes at the works "oxanite" with small quantities of lime are being employed. The

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sludges obtained are free from offensive odour, as are also the tanks.

I am informed that the Medical Superintendent of the Asylum gave evidence before a Local Government Board Inquiry, held at Rhymney, South Wales, last January, to the effect that he was entirely satisfied with the results obtained by the process, and to the effect that the sludges were stored in heaps in the open until when required for use as manure, and that they caused no offence when kept. He has informed me that these sludges make admirable manure for cabbages.

The quantities of chemicals used in the treatment are about 15 grains per gallon of oxanite, about 5 of lime, and about 5 of nitrate.

This exceptionally heavy treatment is employed for two reasons. During certain days of the week, the precipitation tanks are considerably overworked, and it is, therefore, necessary to procure a heavy precipitation to ensure sufficient clarification. The large quantity of nitrate is employed to prevent the sewage with which the effluent is mixed in the ditch from setting up putrefaction.

Chapelizod Works.

The works erected at Chapelizod represent the latest designs by Mr. Parry for applying the oxygen system to isolated buildings, and they have been found most efficient in effecting purification and most convenient in operation.

I have permission from Professor Hartley to append the following expression of opinion by him as to the efficiency of oxanite as a precipitant, and as to the general efficiency of these works:—

"Ballater, Aberdeenshire,
"August 24th, 1898.

"Gentlemen,—In former reports presented to you on the working of the Oxygen Sewage Purification Process I made no reference to the efficiency of the special precipitant which is now in use. As, however, the employment of a material prepared under my direction similar in composition, was the subject of experiments carried out by me in 1887, I am in a position to state that it is the most effective agent for causing the complete and rapid subsidence of sludge from sewage. The sludge dries on removal from the tanks if the liquid is allowed to drain away, and a continual process of oxidation proceeds in the moist mud even until it is dry, oxygen from the air being continually absorbed by the mineral constituents of the precipitant. The highly oxidised products are utilised by the micro-organisms in oxidising the organic matter of the sludge, the action being so energetic so as to cause a rise of temperature.

"In January last I visited, without previous appointment and quite unexpectedly, the works erected at Chapelizod, near Dublin. The whole of the plant, including uncovered tanks, was enclosed in a building only just sufficiently large to contain it. Though there was no ventilation and the building had been entirely shut up since 9 a.m., the air of the building at 3 p.m. was quite free from odour of sewage, there being no noticeable smell of any kind. Everything presented such an appearance of cleanliness that the perfect working of the system was clearly demonstrated.

"I am, Gentlemen,
"Yours faithfully,
"(Signed) W. N. Hartley.

"To the Directors of the Oxygen Sewage Purification Company, Limited, Dublin."

Northallerton Works.

The works at this place have been designed to deal with the sewage of a town containing 4,000 inhabitants, in other words, with about 100,000 gallons of sewage per day. They have only just been started, but I am able to state from information supplied to me by Mr. Shegog, under whose supervision the works are being put into operation, that with the treatment of 10 to 12 grains per gallon of oxanite, and of one to two grains of nitrate of soda per gallon, excellent results are obtained, and that the effluent remains perfectly sweet on keeping.

Cost of Chemical Treatment at Northallerton.

The above quantities of 10 and 12 grains per gallon of oxanite, represents an expenditure, per one million gallons treated, of 29s. to 34s. for oxanite and 12s. to 24s. for nitrate, exclusive of cost of carriage. Against this cost must be considered the very slight amount of labour which is required for working the process, compared with a filtration process, and the fact also that filtration processes necessitate in many localities the pumping of the sewage before treatment, a necessity which the oxygen system would in most cases obviate. This is exemplified at Dundrum, where, owing to insufficient fall, the whole of the sewage would have to be pumped before it could be treated by a filtration process. The heavy charge for filter beds, and for their maintenance, must likewise be taken into consideration.

Another saving in cost of treatment, which can be effected by the oxygen process, when employed on a sufficient large scale, is the possibility of recovering, by simple means, the manganese from the fermented sludges, in a form suitable for re-use as a precipitant.

I ought to add that the use of nitrate of soda and oxanite and other important details of the oxygen process are protected by Letters Patent, the property of the Oxygen Sewage Purification Company, of Dublin.

Methods of Analyses of Sewage and of Sewage Effluents.

I should like to point out before concluding that the experimental results which are given in the earlier part of this statement lay the foundation for an accurate and rational method of analyses of sewage, as well as indicate the lines along which purification should be carried.

The consideration of this subject would, however, make this statement much too long, but I should be happy to give evidence upon it at a future date should this Commission desire it.

APPENDIX.

Giving Designs of Works, Cost of Erection, and Particulars of Working.

By W. Kaye Parry, M.A., C.E.

The Oxygen Sewage Purification Company, Limited. Installation at Dundrum, County Dublin.

Works designed to purify a quantity of sewage not exceeding 15,000 gallons per day.

[See Drawing.] Appendix No. 17 (A)

Cost of works about £500.

The works consist of a series of three deep tanks on the Dortmund principle. Each tank has a central shaft down which the sewage is conducted and a series of arms or spreaders by which it is distributed, the liquid rises through the body of water to the surface and passes out of the tank at the same level as it enters it. The sludge is drawn up from the bottom of the tanks through a central suction pipe connected with a cylinder which has been exhausted by an air pump. The sludge is removed by hand, air dried, and used as manure.

The sewage as it enters the first tank actuates a water wheel by which the necessary supplies of the chemicals are regulated.

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The Oxygen Sewage Purification Company, Limited. Installation at Chapelizod, County Dublin.

Works designed to purify a quantity of sewage not exceeding 1,200 gallons per day.

[See Drawing.] Appendix No. 17 (B).

Cost of works, about £300.

These works were designed after the Dundrum installation had been at work for some years, and the improvements were the result of experience obtained at Dundrum.

The works consist of a series of four circular tanks on the Dortmund principle, but the central shafts, the spreading arms, the suction pipes, the cylinders, and the air pump have been dispensed with.

The sewage after flowing over the wheel which regulates the feed of the chemical re-agents flows into tank No. 1. It passes into tank No. 2 through a low level communicating pipe, and rising to the surface level flows out of tank No. 2 at the same level as it entered No. 1. Tanks Nos. 3 and 4 are similarly arranged.

By means of valves and sluices any one tank can be cut out of circuit for cleaning.

The sludge is drawn off by sluice valves, opening into a central well or sump. A bucket is lowered by a differential pulley, travelling on a circular overhead rail. The bucket can be hung under any one of the four sluices. The valve is then opened, and the thick sludge passes

into the bucket. When the bucket is full the sluice is shut down and the bucket raised to the surface. All this is done from above, without descending into the sump or well.

If a tank requires to be emptied the contents are allowed to flow into the sump, and are then pumped up by a chain pump.

The inside faces of the tanks are finished in Medina cement, trowelled smooth, and can be easily brushed down without emptying the tanks.

One bucketful of sludge is lifted very day. The bucket is fitted with trunnions, and when lifted and detached, drops into a small two-wheel "carriage." It is easily wheeled away by one man. The contents are emptied, air dried, and used in the garden.

The works are in charge of a labouring man.

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THE OXYGEN SEWAGE PURIFICATION COMPANY, LIMITED.

INSTALLATION AT NORTHALLERTON, YORKSHIRE.

Works designed to purify a quantity of sewage not exceeding 100,000 gallons per day.

Appendix No. 17 (C).

[See Drawing.]

Cost of works, about £1,000.

These works consist of two sets of precipitation tanks—one incubation chamber and two biological tanks. They are designed for continuous working.

The sewage passes into the works through the machinery house, working the wheel for the feeding machine, as in other cases.

The liquid flows through the set of three tanks, and then enters the incubation chamber, from which it passes into the biological tanks, and thence to the outlet.

The sludge is swept out into wells or sumps, and pumped up on to the surface by chain pumps; it is then air-dried and removed.

The tanks are designed for continuous working, and not intermittent. Shallow tanks were adopted owing to the character of the ground, but deep tanks on the Dortmund principle would give more rapid clarification.

October 14, 1898. W. KAYE PARRY.

2385. (*Professor Ramsay.*) Perhaps it will be most useful to the Commission if I take your very last sentence first. It runs: "I should like to point out before concluding that the experimental results which are given in the earlier part of this statement lay the foundation for an accurate and rational method of analyses of sewage, as well as indicate the lines along which purification should be carried. The consideration of this subject would, however, make this statement much too long, but I should be happy to give evidence upon it at a future date should this Commission desire it." I should like to ask you generally what you consider to be the meaning of such statements as that "the sewage gives so much ammonia," "so much albuminoid ammonia," "so much oxygen absorption," and so on, if I might ask you for those facts?—I may say that for my own work those convey really no concrete meaning to my mind, as to the real state of the sewage.

2386. To begin with the free ammonia?—The free ammonia, yes.

2387. What do you regard as signified by the presence of free ammonia in the sewage?—The analysis of any crude sewage giving the quantity of ammonia it contained would give an indication of the degree of foulness of that sewage, I think. I regard the free ammonia determinations as valuable with fresh sewage as indicating the foulness of the sewage. On keeping sewage the free ammonia determinations are valuable because they may indicate whether fermentation is going on in that sewage or not.

2388. The sewage as it leaves the human body contains no free ammonia?—No, the solid sewage does not, or very little.

2389. Is that subsequently developed in the sewers?—Well, it is contained in urine.

2390. Free ammonia?—Free ammonia, yes.

2391. In quantities which are appreciable?—Oh, distinctly appreciable. And then, of course, fermentation goes on in the sewers, and the fermentation of the urea in urine is very rapid, and an increase of ammonia consequently takes place rapidly.

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2392. Then passing on to albuminoid ammonia, what does its presence imply?—Well, I may really say, to my mind, it implies nothing so far as sewage is concerned. It is really of no scientific value when dealing with the subject of the foulness of sewage, or with the subject of sewage purification; to my mind it has really no concrete significance.

2393. But it is invariably stated that such and such a process of treatment of sewage decreases the amount of albuminoid ammonia and the conclusion is drawn from that that the process is more or less good?—That conveys no real meaning to my mind.

2394. Can you give your reasons why it conveys no real meaning?—Yes, I can., As I have explained in the paper which I have handed in (pp. 189-191) the organic matters of sewage undergo during purification by natural agencies two successive and distinctly different stages of chemical change; during the first stage the organic matters undergo fermentation or slow combustion, and are converted into carbonic acid, water, ammonia, and organic colouring matters; during the second stage the two last-named products are further oxidized and converted into nitric acid and carbonic acid. The experimental results recorded in Table I. illustrate these fermentative changes, and demonstrate the following facts:—(1) The carbonic acid formed and oxygen consumed by the complete fermentation of the organic matters in sewage are directly proportional to the quantity of the fermentable organic matters in that sewage; (2) the nitric acid formed and oxygen consumed by the after fermentation of the ammonia are directly proportional to the ammonia originally present in the sewage plus that formed during the first stage. Hence if a sample of sewage or sewage effluent be suitably kept or allowed to ferment in the presence of oxygen we can ascertain the quantity of fermentable organic matter in that sample, in terms of the volume of carbonic acid formed and of oxygen consumed by their complete fermentation, and we can determine that volume of oxygen separately and apart from that required for the after fermentation of the ammonia, a possibility of such practical importance, since this second stage of fermentation presents but little danger to river water, unlike the first stage, which in the absence of sufficient oxygen invariably sets up putrefaction. The quantitive relationships between the products of fermentation recorded in Table I. are more clearly indicated in the table headed "From Table I." The products of fermentation are given in columns 1, 2, and 3 of this table. In the last column, headed No. 4, you will see indicated the volumes of atmospheric oxygen actually consumed during the fermentation of the organic matter in the sewage experimented with. Do you follow me, Dr. Ramsay?

2395. Yes.—You will observe in the first experiment the fermentation was not complete, and there were only sixty-four volumes of atmospheric oxygen consumed; but in the next two experiments the fermentation of the organic matter was complete, and there you get 123 in one case, and 132 in another. Those differences are due to experimental errors. If you go on to the second experiment with the third solution you will see 174 indicated as volume of oxygen consumed. That is the volume of oxygen consumed during the oxidation of the ammonia. Having indicated what I consider to be the kind of information we require from the analysis of a sewage or sewage effluent, I am in a position to explain my reasons for regarding the albuminoid ammonia test as of no value for indicating the foulness of a sewage or of a sewage effluent. The sewage which was employed for the experiments which I have just been referring to, gave the following results when examined by the methods of analysis in common use, expressed as parts per 1,000:—

Free ammonia - - - -	0·0475	
Albuminoid ammonia - -	0·005	
Oxygen absorbed from standard permanganate acting in the cold for three hours - -	50·2	*ccs.*

It is only necessary to remark that the above quantity of albuminoid ammonia affords no indication whatever as to the quantity of organic matters in the sewage. This becomes apparent immediately we call to mind the fact that no albuminoid ammonia is yielded by such important fermentable constituents of sewage as urea, and non-nitrogenous substances, *e.g.*, soaps, fats, etc. To bring out my objection to the albuminoid ammonia test

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as clearly as possible, I must ask your further attention to the experiments recorded in Table II. in my paper (p. 191). These experiments were made not with raw sewage, but with a purified product obtained from it after careful precipitation and filtration, a process of purification which had effected the complete fermentation of organic matters originally present in the sewage, and which left only the ammonia and organic colouring matters for fermentation. This fact is revealed at once by the results recorded in the table, the oxygen contained being wholly taken up by the fermentation of the ammonia and organic colouring matters in the sample. The quantitative relationships between the oxygen consumed and the products formed in these experiments are shown by the table headed "from Table II." The ordinary methods of analysis yielded the following results, expressed as parts per 1,000:—

Free ammonia - - - -	0·017
Albuminoid ammonia - -	0·0012
Oxygen absorbed from standard permanganate acting in the cold for three hours - -	16·2 *ccs.*

The quantity of albuminoid ammonia here indicated is just one-fourth that given off by the unpurified sewage, but this is all the information it gives us. It does not tell us what the fermentative tests show, viz., that the organic matters present in the effluent had completely undergone the first stage of fermentation, and were therefore perfectly harmless to river water. It is unnecessary to adduce more evidence to show that the albuminoid ammonia determinations in the case of sewage and sewage effluents have really no concrete value, and that, further, the use of the method for the analysis of such liquids is really unscientific; although, I should like to add, of great value for the examination of potable waters. The only really valuable result I consider in the three determinations which I have just given you is that of the free ammonia, where you see, when compared with the first set, a very distinct reduction of free ammonia, indicating indirectly that you are probably not dealing with putrescent or fermentable organic matter. But even this could not be safely taken for granted without a confirmatory fermentative test.

2396. Might I interrupt you at this stage, Dr. Adeney, and ask you to give us a description of the kind of way in which you test all these—I think it might interest the Commission to know how this test is made?—Yes. The sewage which you wish to examine as to its fermentative properties must be allowed to ferment in the presence of atmospheric oxygen. Generally a crude sewage is too foul to deal with accurately in its raw state, and it is necessary to dilute it with tap water so that the fermentable organic matter in the diluted sewage, and the atmospheric oxygen which is at the disposal of the bacteria in the form of dissolved oxygen, shall be fairly equally balanced. You can effect this practically by making a series of dilutions of the sewage with good tap water, such as I have illustrated in Table I.; thus the first solution in the table marked one in ten, means one volume of sewage diluted with nine volumes of tap water, and again one volume of sewage diluted with nineteen volumes of tap water, and so on. On examining these different solutions after the experiment had gone on some time, it was found that the first solution was too strong; that is to say, putrefactive fermentation had set in, there not being enough atmospheric oxygen in the solution; consequently that experiment, so far as indicating the completion of the aërobic fermentation of the organic matter, was valueless. In all the other solutions, however, the atmospheric oxygen was in excess of the organic matters present, and the successful results recorded in the table were obtained.

2397. One may take putrefactive fermentation as synonymous with anaërobic?—Synonymous with anaërobic, yes. To preserve these dilutions from contact with air during fermentation, they are kept in bottles which are completely filled, and these bottles are stoppered with glass stoppers and turned upside down and immersed in a vessel of water, so as to keep them completely out of contact with air. If you determine the quantity of carbonic acid, atmospheric oxygen, and ammonia and nitrates in these different solutions to start with, allow them to ferment for a sufficient time, and determine the same constituents again, you then have the means of estimating the organic matter that is present in the sewage in terms of the carbonic acid which is formed, and of the atmospheric oxygen which is consumed; in other words, you observe quantitatively exactly what a given volume of the sewage will do if delivered into a stream or into a river. I do not know whether I make myself plain.

2398. I think so, yes?—To summarize my remarks on the analysis of sewage and of sewage effluents, we find from the table headed "from Table II." that we may have a large absorption of oxygen, and the presence of considerable quantities of organic matter indicated, neither of which represent real danger to a river water, so far as putrefaction is concerned. It is quite impossible that these matters could set up putrefactive or anaërobic fermentation, so the very first thing we have to do in analysing sewage, or effluents, dealing with questions of river pollution is to distinguish between what organic matters are not fermented and what are, and to determine the quantity of the former. I need not say that the albuminoid ammonia and the permanganate test will not enable you to make these distinctions.

2399. Then may I ask you, with reference to the column which you head "Total Nitrogen," that is, nitrogen in the fifth column of Table I., that nitrogen has no significance except in showing that the analysis had been correctly performed. That is the residual nitrogen in the gases in solution, I understand?—Yes.

2400. And has nothing whatever to do with the fermentation?—And has nothing whatever to do with the fermentation. You only get an increase in the dissolved atmospheric nitrogen when you have anaërobic fermentation.

2401. Anaërobic fermentation?—But it is an excellent index of the accuracy with which the analyses have been performed.

2402. I think the Commission understand that when the sewage is left in contact with water and air the sewage, of course, has no influence on the nitrogen in the air, but only on the oxygen. The residue of nitrogen which has been estimated, however, shows that the analyses are comparable with one another, and that nitrogen is simply the residual nitrogen from the air, the oxygen having been removed. Then, passing on to the nitrites and nitrates, you regard these as the products of oxidation of ammonia?—Yes, in all cases of sewage.

2403. Does this oxidation take place in one stage or in two? Let me put my question somewhat in detail. Do you regard it as probable that the organic matter first ferments to ammonia by being acted upon by one ferment, and that that ammonia is subsequently turned into nitrites by the action of a second ferment, and lastly into nitrates by the action of a third?—That is my belief. As far as the subject has been worked out, that is the prevalent belief, I believe, amongst chemists and bacteriologists.

2404. Then would you regard the presence of ammonia as a sign that the putrefactive change was going on?—If it were increasing.

2405. Not if it were diminishing?—Not if it were diminishing.

2406. Do you regard nitrates as the product of oxidation of the ammonia or of the nitrites?—That I do not think there is sufficient experimental data to answer definitely. I can only give you the prevalent opinion, that it is first converted into nitrites and then into nitrates.

2407. Would you regard the presence of nitrites as dangerous to health?—Not necessarily. It is only an indication that the fermentation has not been completed.

2408. But a total oxidation of ammonia into nitrates would show that the sewage is no longer dangerous?—Oh, quite.

2409. Is the carbonic acid formed an index of the change that is taking place—I mean the fermentative change taking place—or might it not be caused by the gradual oxidization of organic matter apart from fermentation?—Well, a great number of experiments have been made on that subject, I believe, more particularly by Sir Edward Frankland, and the conclusion, I think, of chemists who have interested themselves in the subject, very greatly influenced no doubt by Sir Edward Frankland's experiments and ideas, is that organic matter is not oxidised by exposure to atmospheric oxygen in solution. If the oxidization does take place, it takes place so slightly as to be inappreciable.

2410. Then, passing once more to the question of oxygen absorbed, have you any views as to the value of the ordinary plan of treating with permanganate of potash, the twenty minutes exposure and the four hours exposure; do you hold that as quite worthless?—I think myself it is quite worthless for giving any exact idea as to the character of sewage. I will give you my reasons. It does not distinguish between unfermented and fermented organic matters, as I have made evident in a previous answer, and is therefore unscientific in principle.

The permanganate of potash acts so slowly upon certain albuminous bodies. For instance, anyone may do this experiment for himself: they may take a bucket of crude sewage and add an excess of permanganate of potash. After a time the permanganate of potash will either be decomposed by the organic matter or be decomposed by contact with its own products of decomposition, and will finally disappear from the sewage as permanganate of potash. Then if you will allow the sewage still to remain in an open vessel it will putrefy, thus showing that the permanganate of potash has not oxidised all the organic matter although added in excess. The organic matter that it does not oxidize is precisely that organic matter which it is of the most importance to determine, namely, the nitrogenous bodies.

2411. Then, to sum up, you regard the examination of sewage as valuable, inasmuch as it has determined in what direction the subsequent fermentation proceeds, whether in the direction of anaërobic fermentation or in the direction of aërobic fermentation?—Yes. I think we must regard a sewage as a fermentable or a fermenting liquid.

2411.* Which may ferment in two ways?—It may ferment in two ways, and what we want to find out in the sewage is how much fermentable matter, apart from its other constituents, that sewage contains, and what length of time it will take to ferment under most favourable circumstances, and what volume of atmospheric oxygen it requires for its complete aërobic fermentation. When we have got those data we know exactly what volume of river water we have to dilute it with in order to prevent it from ever putrefying. If we have a known volume of crude sewage to deal with, and if we know how much atmospheric oxygen it requires for the fermentation of its organic matters, we then have all the data necessary for calculating what bulk of river water may safely receive that volume of sewage without the fear of after putrefaction.

2412. I should like to pass on next to ask you if you have any views on the two rival systems of aërobic and anaërobic fermentation. You hold it is valuable that the sewage should undergo anaërobic fermentation before it is finally aerated?—Well, I think it is fair to say that my study has been almost entirely confined to aërobic fermentation, and that whereas I have published a large volume of experimental work on aërobic fermentation, and therefore have some reasons for the opinions I have expressed, I have no such volume of experimental work upon which to found any solid opinions on anaërobic fermentation, so far as its being of value for treating sewage on a large scale is concerned. Of course, I have met with it in my own experiments, and with my experiments in mind I have been surprised to hear from gentlemen who were working with anaërobic fermentation that they are hopeful that anaërobic fermentation can be induced to proceed so quickly as to be of real value in the treatment of sewage on a large scale. I may illustrate what I mean by reference to actual experiments. I have taken a certain sewage and a very foul one, and I have allowed it to fall slowly drop by drop through about 1½ feet depth of a filter composed of coarse pieces of pumice. I have started this experiment in the evening and I have found next morning that the liquid that has passed through this pumice float has been completely fermented so far as the organic matters were concerned. That is a matter, you see, of the fermentation of a really very foul sewage in the course of a few hours by aërobic fermentation. I have also taken another sample of the same sewage and I have put it in a tall cylinder about 15 inches high, and that has taken eleven days to undergo the same change as completely; here the conditions have been mixed aërobic and anaërobic. Then I have taken another sample of the same sewage and mixed it with nitrate of soda to prevent the putrefaction which takes place in the jar without it. Well, I have found the fermentation to go on quicker, but then it has taken five days under this condition. I have also taken still another sample of the same sewage, and put it in a vessel, completely filled with it, and kept it out of contact with air. That was left in the dark for two months, and apparently the ordinary change had taken place—anaërobic change. There was a slight black deposit at the bottom of the vessel, there was disengagement in the vessel itself of a little gas, and the liquid had become apparently quite clear. I knew, of course, from experience, that if I had uncorked the bottle the stench of it would have been almost unbearable. But I wanted to do something further. After keeping it in the dark for two months, I exposed it to sunlight for five months, and during three months it gave off very considerable volumes of a mixture of nitrogen, hydrogen, and marsh gas, so then this experiment was going on for seven months, but of course that was under laboratory conditions, and there was a condition absent in my experiment which some of my friends who are working on this anaërobic fermentation say is a condition which they can get on a large scale, and which is essential, namely, large surface areas upon which they can induce an extensive growth of anaërobic bacteria in tanks into which the sewage is allowed to flow for the purpose of anaërobic fermentation. When the sewage is continuously exposed under anaërobic conditions to the influence of these organisms it is said that a comparatively rapid action on the organic matters ensues. I should be extremely sorry to throw any doubt upon the work of some of the gentlemen who are working on this question, because I know them to be very earnestly at work, but I should like to say here what I have told them elsewhere, that I think that they ought to give us direct experimental evidence in support of the opinions they have put forward. I think they are working at present on pure hypothesis. They get certain results which they explain as a direct influence of anaërobic fermentation, but which I should feel inclined to explain in another way.

2413. Then to pass to your own special work: you have found that the addition of certain auxiliary matters such as manganese compounds and nitrate of soda has assisted the aërobic fermentation of sewage?—Yes; that is to say, it has assisted aërobic and excluded anaërobic fermentation.

2414. Does their presence exclude anaërobic ferments?—Anaërobic fermentation does not take place apparently in their presence.

2415. I might ask if you think that similar results could be got without such auxiliary means, that is to say, will fermentation take place to the same extent and in as short a time without?—Oh, certainly not. The solid matters in the sewage, for instance, unless they are mixed with something to assist aërobic fermentation, undergo putrefaction and become so offensive that they cannot be allowed to accumulate about the sewage works.

2416. Have you examined at all the effect of trade effluents?—Yes.

2417. On fermentation?—I have. I have made a number of experiments at Halifax—a considerable number—and I do not think the trade wastes are as difficult to deal with as is generally supposed, because at Halifax I may say the nature of the trade waste varies almost every minute of the day, and if works were properly designed so that sewage at different times of the day could be diverted into different tanks, the one impurity from one factory would work against a discharge from another factory. I mean in this way. One factory will discharge large volumes of soap, another factory will at some later time perhaps in the day discharge a large quantity of salts of iron. Well, if those two are kept separate of course you have to deal with them, but if you could mix them together they would precipitate one another and clarify the sewage. I found at Halifax, with a little care as to details, it was quite possible to get a complete clarification; it was quite possible if you use manganese compounds to get a sludge which you could preserve in heaps in the neighbourhood of the works without engendering any smell of any kind, and it was quite possible to get an effluent, to which, I have been informed, if you added half a grain of nitrate of soda per gallon you could keep in stoppered bottles and it would not undergo putrefaction.

2418. Do you think the presence of trade effluents—of course, it is a very wide term, but perhaps you could give us your ideas as to whether acid, for example, is hurtful to aërobic fermentation?—Aërobic fermentation will not not take place in a distinctly acid sewage, and therefore acid is detrimental to sewage purification. Any works discharging waste liquors into a stream or into sewers should, I think, be compelled to neutralise their acids, or at least they should not be allowed to discharge them in any large volume. Of course it would take a large volume of acid to render even distinctly acid the sewage of a large town, for instance, like Halifax. The local authorities might with discretion allow a considerable quantity of free acid to be discharged into the sewers, knowing that the alkalinity of the sewage would take up a large quantity. But there should be a limit placed upon that, and the limit should be that quantity which would give a distinctly acid reaction to the sewage. That limit should certainly be enforced.

2419. Then with regard to alkalis or lime, have they any influence?—The same thing with lime. A sewage

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should not be allowed to become strongly alkaline or distinctly alkaline, and you, moreover, cannot allow any latitude to manufacturers in this case, because it is well to remember that sewage rapidly becomes distinctly alkaline itself, and alkalinity is one of the things to keep down in sewage treatment; at any rate, not to allow a greater alkalinity than is due to the natural fermentation.

2420. Are there any other effluents than iron, acid, or alkali that you would regard as prejudicial?—Well, not for sewage treatment, because iron salts would assist in clarification, so that I should not regard iron compounds, unless they were too acid, as a serious matter. Of course, large quantities of soap are a serious matter. Large quantities of soap are very serious things to deal with in sewage works.

2421. To sum up, you would regard it as essential that a sewage should be purified to such a point that it will no longer undergo either aërobic or anaërobic change?—Yes—well, I do not know about aërobic change.

2422. That would not matter?—That would not matter, I think. Of course, one's ideas must vary with local conditions. If a sewage is discharged into a river—into a river above the intake, for instance, of a water supply for a town, then the purification of the effluents should be carried as far as possible, which would be, of course, indicated if the effluents were rapidly nitrifying. In the cases of many small towns and villages which are more happily situated, however, I do not think it is necessary to require a purification beyond that which will ensure that the effluent will not putrefy when it gets into the stream, or set up putrefaction.

2423. Have you considered the question of standards at all—standards of purity?—Yes, I have.

2424. Do you think that any reasonable standard could be devised, which would take into account—what shall we call it—putrefiability?—To take into account local circumstances, perhaps.

2425. No, I mean the liability to putrefaction. Would it be sufficient to say that sewage could be turned into a stream which will not undergo anaërobic fermentation?—I think I might put it in this way: Suppose you have given the volume of the daily flow of the sewage, and the volume of the minimum daily flow of running water into which the purified sewage is to be discharged, you could formulate your standard of purity thus. The effluent to be of such purity that, when diluted with good water to an extent equal in proportion to that to which it would be diluted when discharged into the said running water, it would not, when kept in a close vessel, suffer putrefactive fermentation.

2426. It would be impossible to make an universal standard on those lines?—Oh, I think not, and I think it would be a great hardship to small towns and villages to make any hard and fast standard. A standard should vary with local circumstances, I think.

2427. (*Sir Richard Thorne.*) May I take it from that answer, Dr. Adeney, that you are of opinion that standards should vary under local circumstances. Have you ever formulated any idea as to how standards could be adapted to local circumstances?—Oh! I think, yes.

2428. I think it would be interesting to the Commission to know what views you have arrived at on the point?—Well, it is quite possible, by the methods of study which I have employed in my own work to determine exactly the volume of atmospheric oxygen which any effluent or sewage will absorb during its complete conversion into a harmless condition. That factor should be determined for all effluents, I think.

2429. For each effluent separately?—The standard might be formulated on these lines, namely, upon the quantity of atmospheric oxygen which a given volume of the effluent would consume on keeping a certain number of days it should be, say, within a certain quantity.

2430. Have you thought at all how that could be carried out administratively; what body would determine that, and enforce it?—You would require certainly the services of a chemist, or a medical officer of health, who has been trained in the necessary chemical operations.

2431. That is obvious, but I mean, what body would enforce the decisions that he comes to, or the views that he arrives at?—I do not know myself; I am not sufficiently acquainted with this country. I should have thought the Local Government Board would have been.

2432. You have not thought out the administrative aspect of it?—No, I have not.

2433. Should I be right in assuming from your Table I. that, when you get a dilution of sewage with water of one of sewage to 20 to water, that that mere dilution will give you results which are satisfactory to you?—In very many cases, perfectly.

2434. Then does it not come to this, that, if any authority will deliver their sewage at the rate of one in 20 to the amount of unpolluted river water into which the sewage flows, that the whole question is solved?—The whole question is solved, provided that they do not let any solid matter in with the effluent.

2435. Then this dilution, plus really efficient straining, would solve the matter?—In many cases, I am of opinion that it would. Of course, there are some sewages apparently which are exceptionally crude, and then you would have to raise the limit of 20 somewhat.

2436. But, after all, it is a question of dilution and getting rid of the solids?—Yes, that is largely so. Of course, there are certain conditions that the effluent should not be acid, that it should be neutral, or but very faintly alkaline, and that it should contain nothing inimical to fermentation.

2437. But the fermentation has to take place in the stream under the circumstances you name?—The fermentation has to take place in the stream, yes.

2438. You explained, I think, why you would avoid acid in sewage, but I am not quite sure as to your views with regard to the alkalinity of sewage, which you said should be avoided?—Alkalinity beyond a certain limit is very inimical to bacterial fermentation, and bacterial fermentation becomes extremely slow when the alkalinity rises above a certain limit.

2439. Then the objection is practically the same with cases of acidity and cases of alkalinity, that it prevents the bacterial processes?—Yes. The only thing is that you can allow a wider discharge of acid than alkalinity, because your sewage is already decidedly alkaline, and if in large volume will, of course, take large volumes of acid to neutralise it.

2440. Now, although you have referred to the operations of micro-organisms in sewage, I gather from your experiments that these operations have been purely chemical?—Purely chemical, yes. The organisms which have taken part in my experiments are those mixed organisms natural to water.

2441. Now, taking the admission of sewage in the diluted form, in which you have rather advocated it, and assuming that it contains at a given time a marked proportion of typhoid bacillus?—Yes.

2442. Would you rely upon the fermentative processes in the stream to get rid of that?—Well, if that water is to be drunk, then the limit of dilution would not do. Then the purification of the sewage must be carried to a very careful extent indeed.

2443. Before it goes into the stream, or afterwards?—Oh, before it goes into the stream.

2444. Then you do not, as a matter of fact, so far as public health is concerned, rely upon dilution?—Oh, yes, I do, if the river water is not to be drunk.

2445. I said for public health purposes?—Oh, for public health purposes, I am of opinion that there ought to be no fear from pathogenic germs, from purely public health considerations.

2446. But surely the greatest public health consideration is the use of the water for potable purposes, is it not?—Then, of course, as I have already stated, if a river water is to be drunk, I think the question of purification becomes a very serious one; that is to say, any volume of sewage effluent is discharged into a river above the intake for any water works for the supply of a town or village, the question becomes a very serious one indeed, and the standard should be very high, so far as purity is concerned, because I am of opinion myself that no water, no surface water, of any kind should be drunk except after efficient filtration. I believe myself that filtration is the only safe process to put water to, if that water is to be drunk.

2447. I suppose I may take it from what you have said, that you have made no actual experiments with regard to any of the pathogenic organisms?—No, I have not.

2448. I noticed in one part of your evidence in chief, or, rather, in two places, you refer to the fact that the chemical changes necessary to produce the result which you wish to attain are most rapidly effected in those instances in which oxygen is supplied in the free atmospheric form?—Yes.

2449. May I ask you if you are in any way referring to some systems that have been advocated of automatic

aerating filters?—Oh, none whatever. I am simply referring to what I consider, other circumstances being equal, the best process of dealing with sewage, that is, by filtration undoubtedly, apart from the question of expense.

2450. And yet you say at one point: "I refer to the "process of natural or artificial filtration, in which the "filtering material exposes large surfaces upon which the "bacteria may grow and accumulate, and the interstices "between the filtering material provides store spaces for "the atmosphere"?—Yes.

2451. There you must be referring to some definite form of filtration, are you not?—No; filtration through porous land, or an ordinary filter bed.

2452. But I suppose that the value of a filter would depend upon the facilities which the oxygen has of penetrating into its pores?—Oh, yes, the more porous the material the better.

2453. And the more exposed to continuous oxygenating processes?—Of course, taking an ordinary filter, it will hold a certain amount of atmospheric oxygen, and no more. When that has been consumed, what you have to do is to stop using that filter, and use another, and let it become re-aërated.

2454. I have rather really tried to avoid mentioning any special form of filter, but do you know Colonel Ducat's proposal, which he submitted to us yesterday?—No, I do not.

2455. I notice that, according to the plans which have been carried out and to which you refer, you get a sludge?—Oh, yes.

2456. I suppose if there are any systems which would avoid a sludge, that is a very important matter, is it not?—Under those conditions where it would be difficult to get rid of the sludge, yes.

2457. But it is always an expense, if it is not a difficulty, is it not?—Well, now, at Dundrum, where a sludge is being obtained with the use of manganese compounds as precipitants, there the sludge is most carefully preserved by the Medical Superintendent, and used as a manure in his cabbage garden, and he has found it a most excellent manure, and I think I may say from what he has told me, that he would regard it as a loss to lose that manure.

2458. That would be the sludge which results from those special works?—Yes.

2459. But I suppose you know that the sludge is a terrible embarrassment to authorities who cannot get rid of it?—Oh, yes, and if precipitated with lime or alumina, or the like, it becomes extremely offensive, but it does not if it is precipitated with manganese.

2460-2. (*Chairman.*) Would you mind giving us a short description of the diagrams?—Certainly.

(The witness here gave a description of the diagram of the Northallerton Works, which he had handed in with the paper giving his evidence.

2463. (*Chairman.*) How long has that been in operation?—It is only just started at Northallerton. At Dundrum it has been in operation since the year 1892.

2464. (*Dr. Russell.*) Is this Northallerton?—Northallerton. It has just been started; in fact, it is not in complete operation I believe yet.

2465. (*Chairman.*) Are the others the same as that?—I have referred to three works, my lord, in my evidence, and these are three drawings—a drawing of each installation to which I have referred.

2466. But the principle is the same, is it?—The principle is the same.

2467. (*Mr. Killick.*) In speaking of the effluent which might be admitted into the streams you assumed that the streams were pure?—Oh, yes.

2468. As a matter of fact the streams are not pure?—Then, of course, that will have to be taken into consideration.

2469. Therefore the tests will have to be the combined effluent and the stream?—Oh, yes.

2470. And that would make it in the present condition of affairs a very much more rigid standard?—Oh, yes; that would have to be done, but still, of course, if the question of purification is really dealt with for every town and village, and the necessary standards are put forward, then we ought to look to our streams being in a good condition. However, that is a question which the chemist who would be engaged in really determining the data for these standards would have to go into.

2471. Streams are not pure at present, and to bring about a pure stream you would have to begin the purification at the top?—Yes, you would.

2472. And so carry it down?—Yes.

2473. Which would mean a very great length of time. In order to get any work done you must begin all over the stream at the same time?—Yes.

2474. Therefore you would have varying standards for every effluent?—Oh, yes. I was simply wishing to put forward a principle. What I think is a very serious matter is putting forward a standard which is unnecessarily high, the pecuniary expense of obtaining which would be really a serious matter for a small village or a small town, or even a manufacturing town.

2475. And the usual tests used in England, the absorption of oxygen from permanganate, and the albuminoid ammonia test you put no value upon?—I put no value at all. You could not really formulate standards upon those. In fact, that is really the reason why chemists have really not attempted to put forward standards other than those put forward by Sir Edward Frankland by the medium of the Rivers Pollution Commission.

2476. Still, a great many chemists in England are using those tests?—They are the only ones they have had to employ. The fact is, the question had not been scientifically worked out until quite recently. I believe I am one of the first who has worked on the subject on strictly scientific principles. This is really the reason which leads me to make assertions which I fear may look somewhat egotistical.

2477. (*Colonel Harding.*) Am I right in understanding that your opinion as to the worthlessness of the usual chemical tests of sewage effluents by oxygen absorbed and albuminoid ammonia arises from this fact, that you think it is less important to estimate the amount of organic matter in an effluent than to estimate the character and the condition of that organic matter in reference to future fermentation either of putrefactive or of aërobic type?—That is so, precisely.

2478. So that really what we want to find out in regard to an effluent to judge whether it is fit to be turned into a stream or not is whether it is liable to putrefactive change or to ordinary aërobic fermentation?—And to what extent, yes.

2479. I understood you to say that in your opinion mixing an effluent from natural precipitation with twenty times its volume of fairly pure river water would be a safe thing to do?—In many cases.

2480. Provided the stream were not used for drinking purposes?—It would in many cases if the precipitants used were not such as were hostile to bacterial fermentation. Some precipitants are. Lime and alumina are.

2481. Then fermentation of one or other kind you must have?—You must have.

2482. And aërobic fermentation produces a change which is not objectionable?—No; it is not an objection *per se.*

2483. And that is the change which takes place by the dilution of the effluent with twenty times its volume?—Yes.

2484. That is aërobic fermentation?—Yes.

2485. Then where you have not the advantage of a stream of fairly pure water and of twenty times the volume of the effluent it is necessary there, in your opinion, to supply the effluent with oxygen by other means?—By other means, yes.

2486. Several means have been suggested. You alluded yourself to an experiment, a laboratory experiment, which you had carried out by flowing sewage over a surface of pumice?—Yes.

2487. Merely a dropping over?—Merely a dropping over, and then it percolated through the pumice.

2488. In that case it obtained the oxygen in the interstices of the pumice stone?—Yes.

2489. But I think I must have misunderstood you to refer to that as anaërobic change?—Oh, you did; it was aërobic change.

2490. That is of the character of Colonel Ducat's principle, in which he passes the effluent downwards through a considerable layer of either coke or cinder or clinker

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matter?—I do not know Colonel Ducat's principle, but anything of that kind would be somewhat similar.

2491. It is somewhat similar, and you found in your case that the fermentation was of an unobjectionable character and fair rapidity?—It is the most rapid obtainable so far as science can say.

2492. You did not carry it on sufficiently far to see whether the matters left behind in the filter were ultimately digested, did you?—I think I may say this: the only things left in the filters were the bacteria themselves.

2493. In regard to one point, as to the organic matter in an effluent, have you given any attention to the amount of the organic matter in an effluent which is living?—I do not know that I quite understand your question.

2494. Well, it is believed that in certain effluents, especially those from intermittent filtration, a good many of the matters visible in the effluent after precipitation and keeping several days are living matters?—Oh, yes.

2495. You would not consider that that matter was objectionable, because probably you would consider that it was matter which would not be liable to further fermentation?—I should not, if I understand your question correctly. If it is a mere cloudiness in an effluent which is otherwise freely supplied with aërobic conditions, I should not regard any cloudiness of that kind as detrimental.

2496. Would you consider the presence of micro-organisms and of other organisms of a larger kind objectionable in the effluent?—From experience I should say certainly not.

2497. It is not putrescible matter?—Oh, certainly not.

2498. They are organisms of the same kind which you meet in a fairly pure stream?—And which are really the agencies which effect the purification.

2499. Therefore the estimation by albuminoid ammonia or oxygen absorbed of these living organic matters would be misleading?—Very misleading. It so happens that they give decided quantities of albuminoid ammonia.

2500. Now, as to the scheme of Northallerton, which has just recently been started. I understood you to say that it consisted mainly of precipitation tanks, the precipitant being the material which you call oxanite?—Oxanite, yes.

2501. Did I understand that there was subsequent filtration?—No.

2502. No subsequent filtration?—No; no subsequent filtration.

2503. In addition to the oxanite there is an addition of one grain per gallon of nitrate of soda?—Of nitrate of soda.

2504. Then that acts as a precipitant?—It does not act as a precipitant, that is added to supply oxygen.

2505. For further change?—For further change.

2506. Then you do not think it is necessary to filter the effluent from such precipitation?—No; not under the conditions of Northallerton. I think it would be an unnecessary expense to them.

2507. And you have found that the effluent from such tanks on being kept remains clear and is free from smell and from putrefactive change?—I am informed by the gentleman who is putting the Northallerton installation in operation that he has taken several samples and kept them in bottles, and I speak from memory, but in about, I should say, fifteen or twenty, I only remarked three which were noticed as giving a slight offensive smell on keeping; and then, of course, it must be remembered it has only just been put into operation. The precipitation had not been perfected, but the great majority of the samples which he described to me as having been kept in bottles remained perfectly sweet.

2508. In the interesting draft that you have brought before us there is a reference to the addition of nitrate of soda to the effluent which is passing from precipitation tanks to filter beds. Do you advise that course at all?—Oh, under some circumstances I should advise it most strongly. Under some circumstances, as I have said before, when an effluent of high purity is required you must filter, and if you used a little nitrate of soda in addition to the filtering you would be able to filter very much more efficiently, and in all probability would be able to reduce the filtering area, which you would have to otherwise employ if you did not use nitrate of soda.

2509. Then the addition of so small a grain as one grain of nitrate of soda to an effluent passing on to filter beds, you think would lead to a giving up of sufficient oxygen really to have a marked effect upon the filtrate?—On, certainly.

2510. I do not know if you would care to answer this question, but is the use of nitrate of soda in that way a thing which is protected by any patent right?—It is. The use of nitrate of soda is protected by a patent both in America and in this country. I do not know that a patent in this country is regarded as a valuable one very often, but I believe that an American patent is, as a rule, regarded as a valid patent. You must not forget that in most town and village waters there is already decided quantities of nitrates in the town supply.

2511. Just one other question. At Northallerton, are you dealing with domestic sewage?—Yes.

2512. Pure and simple?—It is practically, I think. There may be one small factory, but it is practically domestic sewage.

2513. (*Dr. Russell*) As to the value of albuminoid ammonia, you say the substance of these micro-organisms on analysis turns up under the category of albuminoid ammonia?—Yes.

2514. But that the importance of these organisms depends upon their functions?—Yes.

2515. (*Sir Richard Thorne.*) Should I be wrong in assuming that apart from such organisms as are mischievous, I refer to the pathogenic ones and those associated with putrescible processes, you see no harm in abundant micro-organic life in a sewage effluent?—Oh, dear no.

2516. None?—Oh, no.

2517. Then those people who count heads, so to speak, and tell you there are so many thousands or millions of micro-organisms in a certain amount of sewage effluent, refer to processes to which you attach no value?—No; I do not think even bacteriologists themselves now place very much value upon the numbers in a sewage effluent.

2518. (*Chairman.*) I just wanted to ask you one or two questions about land treatment. I do not know whether you have any experience of it?—I have seen some of the bad effects of sewage being passed on to land in contaminated well waters.

2519. You have?—Yes.

2520. Could you give any instances?—I have one instance in my mind, which came under my notice professionally. It was the case of Ennis in co. Clare. The sewage depôt of Ennis was placed on rather high ground, and the soil is of an open, porous character, and I was asked by a client to examine his well water (a shallow one), which was about—oh, I suppose, 200 yards away from the depôt. I am speaking from memory now, so that I am not quite certain of that—it was about 200 yards away, I think. On examination of this well water I found it to be distinctly polluted with sewage matter. As a matter of interest I made enquiries as to the health of Ennis to ascertain if there was any reason for thinking that this poisoning of the subsoil water was general, and whether it had affected the health of the inhabitants, and I was told that there has been cases of epidemics, especially in the autumn in more than one year, at Ennis. It appeared to my mind those epidemics were probably due to the pollution of the subsoil water, by the sewage cesspit which had been formed by the side of this sewage depôt to which I have referred.

2521. Have you ever done anything in the way of analysing the effluents after land treatment?—No, I do not recollect having analysed any. No, I have not.

2522. Then you would not be able to compare the effluent from your own system with any effluent that comes from land treatment?—I am afraid not; no, my lord.

2523. You probably cannot tell us from experience then how far land will purify when it is frozen?—When it is frozen?

2524. Yes?—Of course filtration by land treatment becomes a matter of great danger under such condition, because of the cracks which are formed in the ground, through which the sewage may pass unpurified, and may set up putrefaction afterwards in the subsoil water, or to directly poison the subsoil water with pathogenic germs. I believe a case of this kind has been recorded by Professor Koch in Germany. I am sorry I cannot give the reference at this moment.

2525. Would you have any opinion as to whether it is right to keep milk cows on a sewage farm?—I think yes, if the sewage farm is most carefully worked. Milch

cows of course must never be put near the grass which has been recently treated with sewage because of the danger of putrescent matter and pathogenic germs in the grass itself, but I think it is quite evident from the experience at Birmingham of the sewage farm there, that with proper care milch cows can be kept upon a sewage farm with safety. I have seen a very large number there quite recently, and they certainly looked in a most healthy condition, and I was told of no complaint amongst them, but it should I think be only under the very strictest care that cows should be allowed to graze on or near land that is utilised as a sewage farm.

2526. You think it would be necessary to take great care that the cows should have no possible access either to sewage as a liquid which they might drink, or to grass recently treated with sewage which they might eat?—Oh, the greatest possible care.

2527. (*Sir Richard Thorne.*) In answer to his lordship's questions just now you said that you had identified epidemics with the use of water diluted by sewage effluent, will you kindly state what the epidemics consisted of?—Well, I should not like to say that I identified it. I formed the opinion in my own mind of the cause of these epidemics. *Mr. W. B. Adeney, D.Sc., F.I.C.* 20 Oct. 1898.

2528. What were the diseases in question?—Intermittent fever, low fevers, and approaching even to typhoid fever.

2529. I do not know that I quite understand the bearing of your answer?—I had better not answer that in explicit terms.

2530. For example, I do not understand an approach to typhoid fever; it would either be typhoid fever or not typhoid fever?—I mean cases of typhoid fever have also occurred there.

TENTH DAY.

Wednesday, 2nd November, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary*.

Mr. H. MARSHALL WARD, Professor of Botany, University of Cambridge, F.R.S., D.Sc., called; and Examined.

2531. (*Chairman.*) You are, I think, Professor Marshall Ward, Professor of Botany at Cambridge?—Yes.

2532. Are you acquainted with the prevailing or proposed methods for the disposal of sewage?—Not with the machinery of any particular method of disposal, but the general questions involved in the disposal of sewage, I think I may say, I am acquainted with, and I know generally of course of one or two different methods. Some involve standing for some time, and others involve standing over special beds and so forth; but it is chiefly with regard to the general problems which must apply to sewage as to the decomposition of manure in soil, and other organic bodies which would be very similar to those found in sewage, that I can speak.

2533. What kind of mixture may sewage be regarded as?—I should regard it as a mixture containing a large quantity of water holding in solution certain organic bodies obtained both from animals and from plants; containing certain quantities of salts, and of animal excreta like urea, and especially vegetable remains like cellulose and certain solid *debris* of animals and plants; and mixed with these, of course, products of their decomposition, in various stages of simplification, as they are breaking down to simpler and simpler things. Then there would be contained larger or smaller quantities of gases (also partly products of their decomposition), such as carbon dioxide and ammonia, and bodies of that kind; in fact, the products of decomposition of animal and vegetable nitrogenous and non-nitrogenous bodies.

2534. And what kinds of problems are considered in the destruction of such materials?—I should say fermentation, in the broad sense of the term: fermentations of various kinds leading to the destruction of the nitrogenous bodies, and in the end to the breaking down of these bodies into quite simple, harmless constituents, like carbon dioxide, ammonia, and water, and indeed some of these, ammonia especially, being eventually further altered; and then fermentations of bodies like cellulose, of which we have of late come to know something, which would be broken down into partly gaseous and partly solid constituents, carbon dioxide and water in the end; and, in fact, the breaking down by fermentative processes to such constituents as could be used later on by plants in building up—as food for plants, in the widest sense of the term—food for plants, because it not only applies to what plants derive from the air (a good deal of carbonic acid in the end is obtained in the air), but also and very specially to the materials which they obtain by their roots from the soil. In that way, if they can only reach the sphere of activity of higher plants we shall get them built up again into bodies very similar to those from which they have been derived. I should say, in general, the great problems to be considered are the great problems of fermentation, the breaking down of complex bodies under the activities of living organisms. *Mr. H. M. Ward, F.R.S., D.Sc.* 2 Nov. 1898.

2535. What agency may we consider valuable for this?—Fungi and bacteria, in the broad sense. An immense amount of work has been done during the last quarter of a century on the products of these organisms, these plants, which is now accepted by all great authorities: and from the particular problems offered by sewage, I should say, owing to the large quantity of liquid that there is, that bacteria would be concerned more than the higher fungi; but there may be many circumstances, circumstances which I could imagine would be brought about by the method of distribution of the sewage over solid particles and so forth, where higher fungi also might be concerned; microscopic, of course, but still plants of greater complexity than bacteria. The action of these fungi and bacteria in nature may be looked upon as that of scavengers. First, they get rid of the mechanical accumulation, not only of the kind of dejecta that we should expect to find specially in sewage, but also of things like fallen tree trunks, and dead leaves, and particularly bones and bits of animals that are buried, and so forth. It is not difficult to make a calculation which shows the great probability that in a finite time the globe would be quite uninhabitable if it were not for this scavenging action, so that the first great action of these agencies is to get rid of the mechanical obstructions to life. But, secondly, I should lay great stress on the way in which they send back into the environment chemical bodies which would otherwise be locked up, and which would gradually, if it were not for the liberating action of bacteria, so accumulate in this locked-up condition, that there would not be the material for life. And you could illustrate this subject, I should say, by such cases as the preservation of only slightly buried or slightly protected bodies in dry climates, like flowers and paper and other putrescible substances in a

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climate like that of Egypt. And, again, by the burial at great depths, where these organisms cannot reach them, of beds of leaves, pieces of wood, and even of other organic remains. These points are, no doubt, concerned in the preservation of fossils. And, of course, lastly, I should bring as further proof that the agents concerned are especially these living organisms the whole of our modern knowledge of what we call sterilization, for getting rid of these bodies, and thereby keeping organic putrescible substances unputrified. We have nothing to do but to take a flask containing such substances, which if left merely plugged with cotton wool, into which the air can slowly diffuse backwards and forwards, will putrify, *i.e.*, will ferment very quickly: and it has been shown, as we know by most careful proofs now, that this only occurs if these organisms gain access. We may have the same flask of material with free access to air, but which has been subjected for so many minutes or hours, to a temperature which will kill all organisms, and it will keep for weeks, months, years, and not go bad. That I consider as the final proof, as it were, that the real agents concerned are not only bodies of a definite size, but living bodies, bodies, that is to say, which can be killed, provided they are exposed to such a temperature as they cannot withstand, and this temperature in most cases lies below 120° Centigrade—in most cases much below that.

2536. Then you have made investigations into the modes of life and action of these fungi and bacteria?—Yes; I have been for some years especially interested in the actions of moulds and destructive fungi of all kinds, and have of late years been specially concerned with problems of bacteria, particularly in the river, and to a certain extent also with bacteria in the soil, and in marshes and under water.

2537. And are the organisms that you find in the rivers and pools and marshes and in the soil, etc., similar in nature to those that occur in the sewage?—There seems to be no doubt of it so far as the few observations—really careful observations—on sewage have gone. I find over and over again the same kinds described. One could easily give a list of half-a-dozen of the common forms. We are relying, of course, on our present methods of recognising these very difficult organisms, for they are very difficult, but one sees in the reports where sewage has been taken and examined for organisms, the same species named as are found in the soil, and although in very clean river water one does not expect to find many of them, occasionally they are found in any ordinary river, and sometimes they are found in considerable abundance—*e.g.*, forms like bacterim-coli, forms like the whole group of putrescent bacteria which have been called proteus, and in earlier years were known under the common name bacterium-tmo, though we now know that that name is a collective name. Again, certain sarcinas and certain green fluorescent bacteria; and, in short, the recognised names are sufficiently distinctive to show that, generally speaking, the same organisms are concerned.

2538. How are the destructive actions in such organisms generally displayed?—The organisms feed upon the products of the breaking down of the complex nitrogenous and other organic bodies found in their environment, and in doing this they destroy a great deal more than they want, a great deal more than is directly utilised for their present needs; so that a bacterium, for instance, may be looked upon as excreting something which attacks, and begins to break down a mass of organic material, as then taking up some of this into its own substance to build up, and add to its own weight; and during that change it, as it were, unlocks the complex substance that it is attacking, and it falls to pieces in various ways. But the sum of it all is a process of change brought about only by a living body, and that is in the broadest sense what is called fermentation. If, however, at the same time there are produced evil-smelling gases, then fermentation is often called putrefaction, and the attempt has been made to separate artificially putrefaction from fermentation, and to restrict putrefaction to the breaking down of these complex nitrogenous animal and vegetable bodies; and also to try and distinguish between putrefaction which gives off no evil odours, as decay, and putrefaction which does give off evil odours. But an examination of the whole subject (and it is easy to give references to the best modern authorities) shows that no such lines can be drawn. Putrefaction is merely a particular case of fermentation, and the most comprehensive definition of fermentation is, changes produced in various bodies by the action of living organisms.

2539. Then, in fact, you would say putrefaction and fermentation are similar processes?—Are similar processes.

2540. Could you give us some illustrations as to what occurs in the decomposition of manure, for instance?—Yes, I think so. In manure we should have large quantities of ammonia being given off under the action of certain bacteria, which are particularly apt to destroy urea. We should also have at the surface ammonia given off by the destruction of more complex nitrogenous bodies. Then it is found that—especially at the surface, but under certain circumstances it is suggested even lower down—this ammonia is gradually converted by two stages into nitric acid, which in the presence of salts like calcium or magnesium would form nitrates; and lastly, we can now no longer doubt that there are certain forms which undo this work, break down the nitrates and the nitrites, and carry them down past the stage of ammonia, until even free nitrogen is evolved; and, of course, that is the most complete form of this destruction that we can figure. There are numbers of urea bacteria now described, and there is no doubt that the conversion of urea into ammonium carbonate is a very common event in all such heaps as the above, and takes place very quickly under the action of these bacteria. Nitrification, the gradual formation of nitric acid from this ammonia, the gradual oxidising of it and building it up into nitrites and nitrates, has now been definitely demonstrated as the act of two distinct bacteria. They have been so carefully worked out that we can no longer doubt that the principal steps even in detail are now known. And lastly under certain circumstances these nitrates can be attacked by other organisms, other bacteria, and the work undone again. Indeed one of the most interesting problems in theoretical agriculture is to see how we can prevent this undoing of that good work by the second series of bacteria, and which undoubtedly goes on in ordinary manure heaps. De-nitrification has now become one of the most important questions concerned in this destruction of organic bodies.

2541. And are these processes influenced by difference in aëration and temperature and other conditions?—Yes. Many bacteria are aërobic and many others are anaerobic, and in those cases the access or otherwise of air is of the utmost importance. Then again we know bacteria which will grow—not only live but grow—at temperatures close to the freezing point, 0° centrigrade; and we have bacteria described not only by one but by at least two good authorities, which will not only live but will grow in liquids hotter than we can bear our hands in, that is at 70° centigrade. The importance of this is that in decomposing heaps of manure or decomposing thin sheets of material like sewage the temperature sometimes goes very high, and objections have been raised to the possibility of bacterial action, but there really is no difficulty about that, unless the temperature gets very much higher than it usually does. Still, these thermophilous bacteria will live at very high temperatures indeed. In all these cases we find that there are certain degrees which we may call the minimum. For instance, the minimum of aëration at which the life can go on. And then if we go on increasing this we get to a point which we may call the maximum amount of aëration, while if we go any further it must stop—*i.e.*, at that temperature. And there is a point somewhere between these extremes which is now generally called the optimum, where the actions are going on at their best, and, of course, in any pure culture, in bacteriological work which is concerned with working out a special problem, the thing to do is to get at these optimum conditions, and there is always found to be a range beyond them. So that matters are very much influenced by aëration, the rising or falling of the temperature, the access of water, and even other factors in the environment—light, for instance.

2542. Can you tell us exactly what you mean by aërobic and anaërobic forms?—Most known organisms, fungi and bacteria included, must have oxygen, must have air for respiration just as an animal must. They cannot live unless they have a partial pressure of oxygen, which is comparable to that in this atmosphere at present. But Pasteur discovered in 1861 that certain fermentations were brought about by organisms living in the depths of liquids where it was impossible that there could be any oxygen, and on working the matter out—and it has now been abundantly confirmed—Pasteur showed that these organisms not only can ferment in the absence of air, not only can live without oxygen, but that they cannot do their work in the presence of oxygen. Oxygen acts to them like some other gas, which we are accustomed to call a poison, does to ordinary aërobic bacteria. So that at one extreme we have organisms which do their work in the absence of air, and, at the other, organisms which do their work with the full access of air, and between there are forms which

require that the oxygen shall be at a certain partial pressure. Some very beautiful cases have been examined lately, in which the bacteria can do their work some little distance down below the surface of water into which oxygen is diffusing, but they cannot come higher up unless the pressure of oxygen diminishes, *e.g.*, with changes in the temperature, and it is even suggested pressure: a film of bacteria living just where the supply of oxygen is, say, half what it would be at the surface there carry on their work. And so we have these cases of aërobic and anaërobic, and partially aërobic organisms. But in addition to these there is an extraordinary physiological class of bacteria, still a small one, but very well known in some cases, which are what we now call facultative anaërobes. That is to say, if you grow them in one supply of food material they will do without oxygen, and will carry on their fermentation in the absence of oxygen; if you then grow them on another kind of material—say nitrogenous material, whereas the last one was a material containing sugar—you must give them some oxygen, so that they can be either anaërobic or aërobic, according to circumstances, and they are therefore called "facultative anaërobic." Anaërobiosis was put on a perfectly firm footing by Pasteur, and every series of observations into this group of organisms since has shown how accurate he was in his facts. There is no doubt whatever as to the existence of anaërobic organisms.

2543. Do I understand that the destruction of bodies such as paper and cellulose, etc., only occurs in the depths?—So far as really accurate observations on the destruction of cellulose go that appears to be the case. The cellulose-destroying organisms have been isolated of late, and found to be anaërobes. They carry on their work of destroying vegetable fibre and vegetable cell walls, dead leaves, and so forth in the mud, in pools, and in marshes, in ponds, etc., and it is owing to their action that quantities of marsh gas are given off at various times. And in late researches in Neva mud a cellulose-destroying organism has been isolated, which, provided it is cultivated in the absence of air, fixes itself upon pieces of paper, causes the fibres slowly to swell and dissolve, and in fact destroys this fibre, destroys cellulose, and there can be no doubt that substances like paper are destroyed in that manner in the soil, or in domestic sewage. This occurs only in the depths, but there have been cases described where actions of this sort can go on nearer the supply of air, say at the surface of a liquid, provided some other organisms can protect the anaërobic one from the action of oxygen. We now know several interesting cases of symbiosis where one organism protects the other, and ensheathes it, as it were, with an oxygen screen, and then the latter can carry on its work. So that, although in the particular case of cellulose our actual knowledge is confined to the action of anaërobic organisms, from the behaviour of certain anaërobic organisms in symbiosis with others, partly in these, but more especially in some other connections, it is quite possible that the action can go on not in the depths; and similarly with other of these anaërobic decompositions.

2544. May I ask what you mean by symbiosis?—In certain cases it has been found that actions which could not be produced by one organism alone—fermentations, for instance—can be produced, provided the food-substances have been acted on first by another organism. Many instances of that are known, and in those cases we may speak of metabiosis, life following life, as it were, in successive crops; but there are other cases where the actions are simultaneous, two organisms which are mechanically joined, glued together as it were, by some common investment, will do work which neither of the organisms alone can do, and that we speak of as symbiosis. It must not be forgotten that there are also cases among these complex mixed fermentations where a third set of events is shown to be true, which may be called "antagonism"; where one organism (A) could carry on a certain fermentation provided another organism (B) is kept away from it, but if this other organism (B) is in the environment their action is antagonistic, and the work is not done. That is to say, the physiological action is going on in a different direction from the direction in which either of them alone would carry it. So that symbiosis comes to mean the action together of two living organisms where the action of each does not hinder—at least does not hinder—and in most cases helps the other. One or two cases have now been thoroughly worked out, and from the little we know there must be very many complex cases still existing.

2545. Is it probable that such complex fermentations occur in sewage?—Yes, I think so, judging from what we know of the nitrification and denitrification which are going on, partly upward work, and which is being undone again by a series of organisms; and from what we know of what goes on in marshes and in the mud at the bottom of rivers, of stagnant pools, and so forth, where we have a series of cellulose organisms breaking up cellulose into methane or marsh gas, &c. Supposing water contains certain quantities of sulphates, the nascent methane can decompose these sulphates, and a quantity of sulphuretted hydrogen will be produced. There has even been shown to exist in such sulphate-containing waters a desulphureting bacterium very like the denitrifying one, and which Beyerinck has lately shown attacks sulphates, and so breaks them down that it has been said to be possible to destroy the hardness of water by this bacterium de-sulphuricans, and to use it in boilers where the water containing so much of this sulphate could not be used before. Then, existing under exactly similar environments, we have a series of organisms that take up the sulphuretted hydrogen, oxidise it, store up sulphur in their own cells, and then carry it to the surface, burn off that sulphur, and produce sulphates again. These are one or two instances of complex fermentations of this sort that have been fairly worked out. And when one sees what exists in a mixture like sewage, this kind of thing must be going on, I should say, at various points, according to the circumstances, according to whether it is in motion, or whether it is quite quiet, whether it is deep or shallow, and so forth.

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2546. Is anything known regarding the destruction of fatty matters such as must occur in domestic sewage?—Very little, but something has been done. Fats have been shown to be attacked by some bacteria, and by some fungi, and in one or two cases it is fairly made out that the fats are broken down into glycerine and fatty acids, and then the glycerine is used by the bacteria for food. We have one or two cases which we are only just becoming familiar with, where fungi do this. A few years ago the question of the destruction of the fats of buried animals, which, of course, is always an important question, has been attacked, and there is no doubt of the general fact that fats can be attacked and destroyed by bacteria, although the exact processes are still matters that require further research.

2547. And would these problems be affected by the admixture of mineral and other chemical substances?—Oh, I should say undoubtedly; there can be no doubt of it, if we only take the cases that we know so well where the acidity or the alkalinity of the medium affects the life of the organism. Over and over again it is found that you can grow a bacterium in a medium which is perceptibly neither acid nor alkaline, but as soon as the acidity begins to increase beyond a certain minimum, the bacterium goes to rest, and refuses to work any longer, or even dies, and any action by which you can slowly neutralise this acid as it forms prolongs its activity. Then, again, if you throw into a fermenting mixture where actions of this sort are going on matters like calcium carbonate, lime, and things of that sort, and suddenly neutralise it, I should say you alter the whole series of fermentations that was occurring. That, of course, would be matter of research to work out in detail, but it can be very fairly inferred from our knowledge of the action of acids and alkalies on these organisms, and that must be occurring wherever minerals are thrown in.

2548. (*Colonel Harding.*) You speak of putrefaction as fermentation?—Yes.

2549. Then are we to understand that there are fermentations of two kinds—putrefactive and aërobic?—No. putrefactive fermentation is not necessarily aërobic; many of the putrefactions, indeed, are anaërobic.

2550. Yes. I was rather assuming that, but are we to understand that there are these two kinds of fermentation, putrefactive or anaërobic and aërobic?—Well, the attempt has been made to draw that distinction, but my opinion is that it cannot be held, and you will find that opinion expressed by most recent writers, such as Migula and Lafar and other authorities. They say that it breaks down. The attempt was made to uphold putrefaction as a particular process in which evil-smelling gases came off, and which was brought about by the action of anaërobic organisms. But neither of these characteristics is true. I mean, you may have anaërobic fermentation going on without putrefactive gases and aërobic fermentations with them.

2551. You said just now that the admixture of lime probably affected very seriously bacterial action. Lime is used as a precipitant very frequently, and, therefore, probably the effluent from lime precipitation works will not be in a condition for future purification by bacterial life, would it?—It would depend on how much lime was put in

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and what exactly had happened. The point on which I should only wish to express an opinion would be this, that, if you add much lime to a fermen ation which has been going on for some time, and which is acid, you are certain to interfere with all the fermentation processes which are resulting in the formation of these acids.

2552. Can you tell us what is the action of the sewage fungus that is sometimes spoken of as the sulphur bacillus?—The sulphur bacillus conveys to my mind no quite definite idea. Does it mean one of the sulphate-destroying or sulphur-storing bacteria?

2553. I have usually heard it referred to as the same thing as the sewage fungus?—I am afraid it conveys to my mind no definite idea.

2554. (*Professor Foster.*) It is a fungus—is it not?—exouse me interrupting—which is very apt to appear in the effluent?—It is Beggiatoa probably; one of the sulphur-storing and destroying forms.

2555. (*Colonel Harding.*) It is rather a test in many cases of the character of an effluent if you find what is popularly known as sewage fungus in it. It is a white, greyish matter?—Very thick and fluffy, lining the pipes.

2556. Covering, for instance, decaying reeds in the stream?—Yes. If I may assume that it is Beggiatoa, one of the sulphur fungi, I think I could say something, but under the name "sewage fungus" I should have thought several forms might be concerned.

2557. My knowledge is entirely of the popular kind on this matter, and sewage fungus is constantly referred to by inspectors as a sign of a bad effluent?—Pipes are sometimes choked by Beggiatoa and other forms of bacteria, which are apt to stick to the pipes and grow in the effluent, some containing a good deal of sulphur.

2558. Then passing to confervoid growths in water, what is their action; is it in any way a purifying action, or is the presence of such a sign of purity or otherwise in any water?—The presence of plants containing green material is not necessarily a sign of a pure water. There are certain organisms which are quite green, and which will give a perfectly green colour to water, *e.g.*, Euglena, for instance, and certain blue-green algæ, which live in water containing a good deal of organic matter.

2559. The popular idea is that the presence of what I was referring to as sewage fungus is a bad sign, and that the presence of green confervoid growths is a good sign in an effluent?—Assuming that we mean the same thing, generally speaking, by the sewage fungus, I could quite agree, but with regard to the green, it would depend very much indeed on what the green organism is. It is true there are not many plants that will live in a really bad water from this point of view, *i.e.*, containing a good deal of organic matter, but there are certainly some green organisms that will.

2560. What about the presence of diatoms in water, for instance, kaviculæ?—I am very much surprised if the presence of diatoms in a water is conclusive as to the purity or non-purity of the water.

2561. I am not in any way suggesting whether that is or is not so; I am seeking information from you?—I do not know that it is so at all.

2562. Your idea is that the presence now, for instance, of confervoid growths in effluent water does not reveal any condition that is useful to us?—I cannot see that it does.

2563. You mean that they might be present in a very objectionable effluent just as they might be present in a good one?—I think so, yes. At the same time, I should rather say that I know nothing to the contrary.

2564. Do you know of any alga or fungus or diatoms or bacterium, the presence of which in an effluent might in any way be useful as a test of its purity?—I think we might certainly say that some are the indicators of the presence of certain conditions. For instance, iron bacteria would suggest that there is iron in some soluble form. There are some bacteria which actually work up iron and deposit iron oxide—rust in their walls. Then the presence of the sulphur bacteria—they are the indicators of the presence of sulphuretted hydrogen, and that we should say was a bad water, I should think. I think that the sewage fungus is probably included in those. Then with regard to the higher plants—well, there are a few like chara or some charas and some algæ, which would indicate the presence of lime, not necessarily in very great quantities, but one would have to be very careful in using those indicators. I should imagine that an indicator plant in this connection must be used very much as we use indicator plants in agricultural questions. I mean, we say that the presence of a certain type of weed in a field may indicate that that field is very clayey; but a wet condition can be brought about without the actual existence of clay, and that weed might be found there. The question of indicator plants is very complicated, and without having a special knowledge on the subject in this connection, I should think that it still requires working from a bacteriological point of view.

2565. Then would you not consider the presence of green weeds in a water to be a sign that that water was to a great extent oxygenated?—Higher green weeds, certainly. If you have abundance of higher plants, green weeds containing chlorophyll, growing quite freely and evidently doing well, certainly I should say there is a great deal of oxygen.

2566. (*Dr. Russell.*) I want you to help me to think clearly about the essential difference between the anaërobic and the aërobic process. I suppose we may call a fish anaërobic because it lives in the water, and dies in the air, whilst creatures which do the opposite are aërobic, but in both cases still it is oxygen that is required?—Oh, but we cannot call a fish anaërobic, I think. A fish is breathing oxygen in the water.

2567. That is the very point I want to get at. What is it that this anaërobic bacterium is living on. Is it oxygen wrenched from some combination?—That was Pasteur's theory, that it lived by breaking down the bodies it came into contact with, and obtaining what oxygen it needed from them; but the process is probably much more complicated than that.

2568. But still it is oxygen that the creature is in search of?—We do not know that.

2569. You see I start from the very popular analogy of the fish. I am quite aware, of course, that it is extremely popular, but still there is something suggested to my mind which makes one wonder whether there is not some analogy between this power that the fish has of getting the air in a certain way and the faculty that the bacterium has, in the one case taking free oxygen from the air, and in the other fighting some organised element for the possession of it?—I think there is no satisfactory explanation of what anaërobiosis consists in. It is only that the fact is now so definitely proved.

2570. (*Professor Foster.*) Excuse me, you said, I think, a few minutes ago that Pasteur's explanation of the anaërobic action was that it was a device of the organism to obtain oxygen, and in the absence of free oxygen to obtain oxygen from the decomposition of the body which it decomposed?—Yes.

2571. And that still remains, does it not, as a popular bacteriological explanation of anaërobic action?—Yes.

2572. But I understand you now to say that with your present researches you are not satisfied that that is the whole explanation of the matter?—That we do not know in what anaërobiosis consists.

2573. (*Dr. Russell.*) I suppose sewage to begin with swarms with both aërobic and anaërobic bacteria?—I should say that anaërobic bacteria abound in the depth, yes, that it swarms, and that at the surface anaërobic bacteria may be there.

2574. Then both these classes may, of course, evidently from the very interesting story you have told us, be useful in the ultimate disposal of the sewage. Supposing you take out a portion of the sewage and put it in circumstances such as the septic tank in order to cultivate the anaërobic bacteria, what effect will it have on the aërobic?—The deprivation of oxygen.

2575. Supposing you have this sewage in which you have got bacteria of both classes, both of which in their own way under favourable circumstances may be useful to you ultimately, and in order to give the anaërobic bacteria a chance you put them in favourable circumstances such as the septic tank is said to afford, what will be the effect on the other class of bacteria; will it kill them?—They may pass into the spore stage the circumstances are made unfavourable for them; they are not exactly killed. I am, however, not sure that I am clear what a septic tank is.

2576. We are very familiar with the septic tank, of course; it is the Exeter process. It simply means retaining the sewage for a certain time in a tank, what you might call an anaërobic tank?—Yes.

2577. And a scum forms of the fatty and light matters, and a deposit forms of the heavier matters, and intermediately a fluid passes off which is much improved in its character, and I think it has been found that the number of bacteria in that fluid is very much diminished compared

with the number in it when it enters the tank?—Circumstances in which anaërobic bacteria would be favoured, and aërobic bacteria would be disfavoured.

2578. Disfavoured, yes?—It does not necessarily imply that those that are disfavoured are killed.

2579. They may be anæsthetised—chloroformed?—They may be, so to speak, anæsthetised.

2580. Then take pathogenic bacteria—does that classification divide them in two; are they also anaërobic and aërobic?—Yes, it extends through all the groups of bacteria. One of the first things to know about a bacterium is whether it is or is not capable of being anaërobic. I am not familiar in detail with pathogenic bacteria, but I can say that with certainty, that it does apply to them.

2581. And independent of their pathogenic function they exercise this other influence on sewage in virtue of their method of life?—Unquestionably there are facts—by the bye, there are many interesting facts with regard to bacterium coli, one of the commonest of the fœces bacteria, which would support that.

2582. (*Professor Foster.*) I gather that you speak of all these changes which are produced by these micro-organisms in organic bodies as fermentation?—Yes.

2583. Some of those are accompanied by ill-smelling gases?—Yes.

2584. The evolution of ill-smelling gases?—Yes.

2585. That is, I suppose an incident, is it?—An incident.

2586. And although you may, for convenience sake, speak of all these changes which produce these ill-smelling gases as putrefaction there is really no essential difference between the putrefactive changes and the other changes?—No essential difference can be said to exist.

2587. And the putrefactive changes are not necessarily anaërobic?—They are not necessarily anaërobic.

2588. They generally are?—They generally are if evil smelling gases are given off.

2589. That kind of change which gives rise to an evil smelling gas, and which we speak of as putrefaction, is generally produced by an organism working under anaërobic conditions?—Yes.

2590. But they can be produced by organisms working under aërobic conditions?—Yes, the production of ammonia and ammoniated gases—sulphuretted hydrogen.

2591. Ammonia would not be called an evil smelling gas, I think?—No, ammonia we should exclude. Ammonia can so often be produced in other ways, but put quite generally the giving off of malodorous gases implies anaërobic action, but cases occur in which they are not due to anaërobes.

2592. Is it always a special organism which produces a putrefactive change, and does that organism always produce putrefactive changes, that is to say, changes accompanied by ill-smelling gases?—I should have said not, not necessarily so; the circumstances would affect it.

2593. That is to say, an organism can under one set of circumstances produce a change which you would simply speak of as a fermentation inasmuch as it was not accompanied by ill-smelling gases, and under other circumstances might produce what you call putrefaction?—Yes.

2594. Those circumstances being the material on which it works or the attendant circumstances?—Very commonly the material on which it works, the attendant circumstances of acidity and alkalinity, and of the temperature. I cannot call a definite case to mind for the moment, but I think I may safely say with those circumstances—changes in the environment—would affect its action: that one and the same organism may at one time on the same food act in one way and at another time in another way.

2595. I take it that the action of these organisms is always connected with their reproduction—that is to say, that when you see the organism is active, when it is producing a large amount of decomposition, it is producing that with the view of increasing itself or producing progeny?—Yes, building up its own material, growing larger and becoming more numerous.

2596. You spoke of the bacillus which produced free nitrogen?—Yes.

2597. Does that work only on nitrates or nitrites?—Only on nitrates and nitrites. The cases where it works in the presence of other nitrogenous bodies are believed to be only incidental; that nitrates and nitrites form the substratum is the conclusion.

2598. Putting those on one side, the final end of all these changes being, as I think you suggested in the beginning of your remarks, the production of nitrates as suitable material for the growth of plants, is the antecedent phase to the nitrate always an ammonia phase?—Yes, so far as I know, always ammonia; I know no cases where it has been worked out for anything but ammonia.

2599. So that, regarding nitrates as the desirable goal of the changes, one ought to strive for the reduction of the material to the ammonia stage as an antecedent?—Yes.

2600. To the action of these nitrifying agents?—Yes.

2601. That reduction to the ammonia stage may be produced by a variety of organisms?—By a large number of organisms.

2602. Some of them working in an anaërobic way, and some of them working in an aërobic way?—Yes.

2603. So that, perfectly apart from the circumstances of symbiosis, to which you refer, in order to produce out of the original crude material of sewage the ammonia as an antecedent to the wished-for nitrates, it is not necessary that the process of change should be one of anaërobic condition?—No, I should say not.

2604. But do you think that the changes which take place under anaërobic conditions are more rapid and more powerful than those which take place under aërobic conditions?—That I cannot say. I should think that would depend on many circumstances, and especially on the method of distributing the surface to be worked on by anaërobic organisms—I mean, the rate of aeration or the movement. But whether in one and the same mass of liquid aërobic fermentation or anaërobic fermentation would take place the more quickly, I could not say.

2605. What I rather meant was this: With your knowledge of the organisms, if you wished as rapidly as possible to bring a quantity of the material present in crude sewage to the ammonia condition, would you provide the material with anaërobic or with aërobic organisms?—Oh, aërobic.

2606. Aërobic?—Aërobic.

2607. But why?—Because I should say the decomposition of the nitrogenous material would go on more rapidly.

2608. More rapidly with the aërobic than with the anaërobic?—Yes.

2609. In fact, you regard the anaërobic almost as Pasteur did, as the particular trick which was induced under certain circumstances, but not one which you would consider as the normal process in the events of nature?—Yes.

2610. A large proportion of the sewage must consist of cellulose or allied forms; there must be a considerable quantity of material of that kind in the sewage?—I should think so.

2611. And a good deal of the so-called suspended matter which is not of an inorganic nature is probably more or less allied to cellulose, cellulose being so very insoluble?—Yes, materials like paper, and wood, and any vegetable refuse would, of course, contain a great deal—I mean, comminuted substances, like straw, parts of vegetables that have passed undigested through animals, and such like bodies would contain large quantities of cellulose.

2612. In speaking just now of the question between anaërobic and aërobic conditions, I had in my mind, and probably you, chiefly nitrogenous matters?—Yes.

2613. But did I understand you to say that all the cellulose destroying organisms were always those which acted under anaërobic conditions?—Yes, I think I am right in saying they are all anaërobic.

2614. You do not know at present of organisms which can destroy cellulose, and especially which would destroy simple suspended articles of cellulose and the like under aërobic conditions?—I can recall none. No, they are all anaërobic that have been worked out—all the cases that I am acquainted with concern anaërobic forms.

2615. Then might we infer from that that in the disposal of sewage it is most desirable that at all events a part of the process should be of an anaërobic kind?—Yes, otherwise I do not see how much of the solid material would be got rid of.

2616. Well, we had a case brought before us—Colonel Ducat's system—which is entirely an aërobic process, where he artificially introduces air into his filters, so that, according to his account, the whole of the material is thoroughly exposed to air during the whole process, where

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no anaërobic actions can go on, and yet he states that the solid matter of the sewage which must contain a very large quantity of the cellulose materials entirely disappears?—It is opposed to all that I know of cellulose destroying organisms. I cannot see how merely aërobic organisms could get rid of that.

2617. But is it not possible, or have you any knowledge as to the possibility, of these cellulose destroying organisms working in symbiosis with aërobic organisms?—Yes, that is possible, if they are sheltered from oxygen by an aërobic form. There are two or three cases that show us they might do their work, but they are really working as anaërobic organisms under those circumstances.

2618. Under those circumstances are both these organisms flourishing, do you think?—Yes, I think so, otherwise I do not think the symbiosis could continue.

2619. Both of them are multiplying?—Both of them are flourishing.

2620. You think it quite possible, under conditions like those which I have just mentioned of Colonel Ducat's filter, that you might have going on at the same time anaërobic action and aërobic action?—I think it is quite conceivable.

2621. And probably the two working together would assist each other?—Would assist each other.

2622. So that the change in the whole material might be more rapid?—So that the change might be going on at maximum rapidity. That is quite conceivable.

2623. Then it is not necessary to provide for the destruction of sewage in special anaërobic conditions?—I should say not. Certainly as regards that part of the destruction of these solid bodies it could go on, provided the other organisms are present, symbiotically helping them. Of course, the particular conditions under which sewage is destroyed, as sewage, makes me hesitate a little, because I do not know how deep the sewage tank might be, or how the sewage is decomposed. I am speaking, I should like to say, quite generally.

2624. The sewage in this case is brought on to the top of a filter of broken fragments of clinker—small fragments of clinker, which are arranged in series of layers, and pipes are introduced into these layers, so as to allow air to have free access to the whole thickness of the filter?—Yes.

2625. And Colonel Ducat says that he takes the crude sewage with only large masses screened off, and puts it on the top of the filter, and that as it passes through the filter the whole of the solid matter is destroyed, including in that case a very large quantity of cellulose?—I know of no aërobic organisms that would do that.

2626. But you think it is quite possible?—I see how it is possible if there is a layer of organisms all over this filtering machinery—a layer of organisms which contains, as it were, a core of anaërobic organisms; the latter can do their work, but they are still working anaërobically.

2627. Do you think it would be possible experimentally to ascertain what is going on in such a filter?—Yes, it ought to be possible by the method of strict experiment, beginning at the beginning.

2628. You speak of bacteria acting at a low temperature—for instance, at zero centigrade—at freezing point?—Yes.

2629. That is a special kind of bacteria?—Yes, special kinds of bacteria have been described that do work at these low temperatures.

2630. But the ordinary bacteria, or the ordinary forms of bacteria, working normally at the ordinary temperature, their action would be suspended—probably would be delayed, and possibly eventually suspended at so low a temperature?—Undoubtedly; ordinary river bacteria work very slowly at anything below twelve centigrade, and at ten centigrade you may say their action is suspended practically; I have shown that to be true from actual observation on the rate of growth of these forms.

2631. Then in a filter which was supposed to be destroying the sewage matter by ordinary bacteria, you would expect that action to be suspended when the temperature fell?—Yes.

2632. Unless there are present in sewage bacteria which are capable of acting at a low temperature, which naturally would not act at a high temperature, but might remain dormant, and then act at a low temperature?—Yes, certainly.

2633. That you think is possible?—Quite possible. Changes of temperature would favour and disfavour different bacteria probably.

2634. Is it at all a feature of these bacteria that under unfavourable circumstances, they go into a dormant condition by forming spores and the like, and continue their existence until such time as they find favourable conditions, and then burst out into activity?—Yes, there are cases of anaërobic forms known which pass into the spore stage as soon as oxygen is let in, and thus remain until all the oxygen has been used up again, and then they will grow—they germinate under anaërobic conditions.

2635. I understand you to say that there are some organisms which are always and exclusively anaërobic?—So far as is known they are always anaërobic.

2636. Going, as you say they may go, into the condition of spores?—But as long as they are active they are anaërobic.

2637. And others which are aërobic only?—Others which so far as is known are aërobic only.

2638. And which, if their supply of oxygen is cut off, either die or similarly go into a dormant or spore condition?—Yes.

2639. But there are others which may act both in one condition or the other?—Others which may be both anaërobic and aërobic.

2640. The same organisms?—The same organisms.

2641. As soon as its conditions are changed it adapts itself to the new state of things?—Yes.

2642. Those organisms, are they well known; I mean are they easily recognised; have they morphological features; I mean could you yourself ascertain whether such facultative organisms were present in sewage or not, do you think?—The morphological recognition of forms quickly, one with another, is very rarely possible, but they have been worked at in culture, and they have been shown to change their habit of anaërobism to aërobism. They could be recognised.

2643. Yes, but if I put the question to you, giving you a certain sample of sewage, "does that sewage contain facultative anaërobic organisms," you by adequate research could put yourself in a position to answer the question?—Yes, that could be done by experimental methods.

2644. And it is possible that there may be in sewage perhaps to some considerable quantity these facultative organisms?—Quite possibly.

2645. Which might work under both kinds of conditions, and work with activity?—Yes, quite possible I should say.

2646. Then a great deal has been done, has there not, about the pathogenic character of bacteria?—Yes.

2647. Is it, or is it not, the case that an organism may under certain conditions be harmless, and under certain other conditions be pathogenic?—I should say so, certainly.

2648. You have studied, I think, a good deal the bacteria of the Thames water?—Yes, I have examined a great many bacteria of the Thames.

2649. Were they for the most part harmless, or were any of them pathogenic?—There were some which were shown to be pathogenic by the pathologists; the majority of them were not pathogenic.

2650. That is to say they were pathogenic in the form in which they existed in the Thames water?—In the form in which they were handed to the pathologist, which was not necessarily the form in which they existed in the Thames water.

2651. You think they might have put on pathogenic features by your handling?—That is quite possible—by the culture.

2652. Then it is quite possible for an organism by the change of the circumstances to put on pathogenic features?—Yes.

2653. When the effluent from sewage is discharged into a river stream do you consider it of importance as to whether it does or does not contain a large number of organisms, and especially as to the nature of those organisms?—Certainly, and I should think that the number of organisms would be of little importance compared with their nature.

2654. As to their nature, in what respect?—As to their being pathogenic or not.

2655. Or being such as may become pathogenic?—Or being such as may become pathogenic by culture.

2656. You can conceive that an effluent at a sewage works might contain not a very large number but a cer-

tain number of organisms, and those might be at that time harmless, but discharged into a river might find circumstances in which they became pathogenic?—That is conceivable, but in going from the one medium into the river I should say that it is much more likely that they would become less pathogenic.

2657. They would become less pathogenic?—Yes.

2658. Why?—Because one has found evidence of forms in the river being very weak, very feeble, and it is known that pathogenic forms if they are growing very feebly may be much more harmless or quite harmless.

2659. That is after having remained for some time in a river stream probably?—In a river stream.

2660. So that sewage discharging itself at a point might carry into a river pathogenic organisms, and yet at a certain distance from there those pathogenic organisms would have ceased to have been pathogenic, and that the water might be used for various purposes without fear?—I think it quite possible that that might happen where the organisms were destroyed. How far they were destroyed from the source of entry is matter for research in special cases, but that they gradually deteriorate in the river there is evidence to show.

2661. In answer to questions which were put to you by Colonel Harding, I think I understood you to say that the majority of green plants you may take as indicative of a certain amount of free oxygen present in the water?—Yes.

2662. So that that might be taken indirectly as evidence that that water did not contain sewage material so greedy of oxygen as to be depriving the water of its oxygen?—Yes.

2663. But that there were some organisms even of a green colour which could thrive in water containing little or no free oxygen, organisms which would give a green colour euglena for instance, is that so?—In water I said containing a good deal of organic matter.

2664. In water containing a good deal of organic matter?—How much is present I do not know, but a good deal of organic matter, and probably very little oxygen under the circumstances.

2665. I rather understood from you that the organism euglena would exist under conditions somewhat different from that of an ordinary plant?—Yes.

2666. That it would exist where there was a very considerable quantity of organic matter, and therefore presumably that there was not a large supply of oxygen in the fluid?—Yes, that is so.

2667. So that where any green scum made its appearance, and I suppose there are other organisms besides euglena having the same character?—There are blue-green algæ. Yes, there are organisms which would be called green, which we are in the habit of calling blue-green algæ, of which that is true.

2668. But a botanist on being shown specimens of the scum would be at once able to say whether it was or was not indicative of a condition of things containing little organic matter and probably much oxygen?—Yes, I think he would in the case of the green plants be able to say that pretty certainly.

2669. What I mean is this. You see Colonel Harding wants to know what is the value of the green scum as indicative of the purity of the effluent, and you said that all green plants would not be a proof of the goodness of that effluent?—Yes.

2670. I am now simply asking you if a very easy botanical examination would decide whether that green matter was an indication of the goodness of the effluent or not?—It would decide whether it was one of these plants or not, yes.

2671. Quite so?—And a general opinion could be given as to whether this plant could grow in the presence of much or little organic matter.

2672. (*Professor Ramsay.*) Can you give us any idea of the total amount of solids in sewage. You spoke of its being a very weak solution?—No, I cannot.

2673. It is stated to be four parts in ten thousand. Would it surprise you to hear that that is so?—I am surprised to hear that it is so dilute.

2674. And of that, half mineral. You said that there was some organism which caused nitrates to go back again to nitrogen. Do you know if that organism carries this change a step further and evolves that nitrogen as ammonia?—No, I know of no organism that does that. The formation of ammonia generally occurs during the breaking down of organic substances, or of urea, and in this denitrification process I do not know of any case where ammonia is produced.

2675. I suppose the destruction of cellulose by what we may call the marsh gas organism is a very slow process?—Apparently very slow.

2676. It has been done on a laboratory scale?—It has been done in the laboratory; it has been done in Winogradsky's laboratory.

2677. It is a process which lasts weeks, does it not?—Two or three weeks, I think; I cannot say exactly. I think I can tell you. No, the time is not given, but it will not be longer than two or three weeks in a case of that sort, and fermentation goes on steadily, apparently.

2678. What has struck me as somewhat of a discrepancy between such statements and others which have been made to us by persons who have to deal with sewage processes is this, that the paper of sewage apparently disappears within a day or two, even within a few hours. Can it be the same organism?—We have evidence of the existence of more than one organism which destroys cellulose, but the one which I was referring to is the well-worked out laboratory case, where there is little doubt that he has got the right organism and thoroughly worked it out, but if you look at Van Senus' case of some years before, he showed that two organisms altogether destroyed cotton wool rather rapidly; but there were apparently two organisms, and we are not so clear about that.

2679. Two quicker than one?—We do not know exactly what did happen, whether it is a case of symbiosis or not. I do not quote it, because it is not so sure.

2680. (*Professor Foster.*) Were those both anaërobic?—I believe one is anaërobic and one aërobic.

2681. There is a case then of an aërobic organism acting upon cellulose?—Well, we do not know.

2682. Suppose it is an anaërobic one, it does the work protected by the aërobic.

2683. (*Professor Ramsay.*) I want to ask you precisely about that. Does the one organism coat the other over; that is to say, does the aërobic organism coat over the anaërobic one, or is the anaërobic organism surrounded simply by a colony of aërobic organisms?—Apparently it coats it over.

2684. (*Professor Foster.*) Sphere of influence?—Yes, in some cases—in the case of the nitrogen fixing bacterium, for instance, as shown by the experiments of Winogradsky, it appears to make little colonies, and enclose it.

2685. (*Professor Ramsay.*) Then another point on a remark that you made was the condition of calcium carbonate or limestone. Would not limestone change all the conditions, and might cause a totally different series of organisms to develop?—Yes, like any other great change, it might disfavour some and favour others.

2686. Would it cause a certain set of organisms to act differently, or would it cause one set to be replaced by another?—It could cause others to act differently if you changed the acidity of the medium.

2687. So that it may be a case of replacement, but it might be a case of altered life conditions and other action?—Yes. There are organisms which cannot be grown on acid potato; they can be grown if the potato is made alkaline; but, on the other hand, the same organism may behave differently on an acid medium, or an alkaline medium, and both grow.

2688. Dr. Russell put a question to you as to whether an anaërobic organism required oxygen for its life, and possibly took oxygen from other bodies containing it. We know of three cases of fermentation which might, I think, bear on the subject. Take, for example, the fermentation of sugar into lactic acid, where the sugar is split into lactic acid, without gaining or losing anything; this sugar can be made to ferment into a butyric acid, I think, and there it gives off hydrogen, which is obviously an anaërobic action?—Yes.

2689. And, again, the ordinary fermentation of sugar, of course, is an aërobic action, where oxygen is absorbed. In such a case, does the organism which deals with lactic acid deprive the sugar of oxygen in order to support its own life?—Well, I think not. Pasteur relied on the fact, as he thought, that yeast would only ferment in the absence of oxygen. But that is not so. Fermentation can go on with yeast quite vigorously with plenty of oxygen present. Yeast is not necessarily an anaërobic organism; but it looks as if Pasteur's explanation with regard to the oxygen,

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although it gives us a very good working hypothesis, will not explain anaërobiosis.

2690. I have a difficulty in seeing how the yeast plant can multiply and increase unless it gets oxygen from somewhere?—In the case of the yeast plant it no doubt gets oxygen in the intervals, in nature.

2691. In intervals?—In intervals, and is then, as it were, wound up, but we are getting into the region of working hypotheses. I still say that I think there is no explanation of anaërobiosis.

2692. Just one more question. Does one bacterium ever kill out another; I mean, does one bacterium ever serve as food for another?—I do not think there are any observations showing that. How far they kill one another has perhaps not been investigated. We are dealing with extremely small organisms, very difficult to investigate; but that one organism does inhibit, and apparently kill, another there seems no doubt. Of course, if you extend the question to fungi generally, they do kill each other. I should like to be quite clear there; I mean, I know of no proof that a bacterium definitely kills a bacterium, but I do know of proofs of fungi killing fungi in the broad sense.

2693. And consuming them?—And consuming them.

2694. (*Major General Carey.*) Has your attention been specially drawn to any of the processes of treatment by bacterial action which have been recently introduced?—To the actual processes—no.

2695. To these different processes. I am referring to the special treatment at Exeter?—No, I am not acquainted in detail with any of the processes of treating sewage.

2696. Is it your opinion that a large volume of surface water suddenly admitted as storm water on to the surface of a filter would affect the bacteriological action of that filter?—I should expect it to sweep large quantities away, but it would depend upon whether there was a firm film of bacteria over the surface that was washed, how far it would interfere with their action. I should expect some interference.

2697. But not necessarily a very serious interference?—Not necessarily. I could imagine circumstances under which every solid particle is kept in place with a very firm film which, without knowing anything experimentally of the force with which storm water comes down on to this, I should think need not be washed away.

2698. I understand there are two stages in which the bacterial action is suspended, or practically suspended—that is, at a low temperature, and at a certain high temperature?—Both those circumstances are liable to bring about suspension of bacterial action.

2699. (*Professor Ramsay.*) Can you tell us anything about the degree of dilution in which fermentation will go on?—No, I can tell you nothing in numbers, but I should have thought that the limits were extremely wide.

2700. (*Professor Foster.*) That fermentation will actually take place in an exceedingly dilute solution?—In an exceedingly dilute solution.

2701. The more dilute the easier, is it not?—There might be limits in both directions. There are limits upwards.

2702. There are limits upwards?—If it is very concentrated.

2703. Are there any limits downwards?—I do not know of any limits downwards. I should have thought it would have gone on as long as there was any material there.

2704. You were explaining, in this condition of symbiosis, that you thought in certain circumstances the colony of one form, say, the aërobic form, might encircle the other form, the anaërobic form?—Yes.

2705. But how, under those circumstances, does the encircled form get at the material upon which it can act. It cuts off its oxygen, but it does not cut off its food?—One may suppose that the aërobic one there, in fermenting, in breaking down the substance, renders some of it soluble, which can be passed through, and can be used by the anaërobic form—pass between the organisms.

2706. Yes, the matters in solution might come to the embraced organism—at the same time, there would be a zone round your embraced organism where the oxygen might be removed?—It is quite possible that the only difference between the soluble material which is outside and that which is inside the enveloping zone was that inside there was no oxygen.

2707. Quite so; it is a ring of influence rather than a mechanical ring?—Quite so.

2708. (*Sir Richard Thorne.*) Continuing that point, I understand you distinctly to hold that cellulose is only destroyed by the anaërobic organisms?—The cases that are really satisfactorily worked out apply to anaërobic fermentation.

2709. Well, then, on this theory of an oxygen screen by reason of aërobic organisms surrounding the anaërobic ones, how would cellulose be dealt with at all when the surrounding screen of aërobic organisms would not help in the destruction of the cellulose, or even in the formation of simpler compounds?—Let us suppose that the destruction of cellulose began by the hydrolosis of the cellulose to sugar, to glucose—that would be soluble. It is quite possible that the outside organism could do that, and then this sugar could pass in and be dealt with by the inside organism. Of course, I am only putting these forward as possibilities, but it is quite possible that that could happen.

2710. The point has, I think, considerable practical importance for us, because there is no question with regard to that aërobic filter which was described by Professor Foster when it has got to the naked eye, a transformation in some twenty minutes to half-an-hour of a very turbid sewage, which must contain a very large amount of cellulose into a perfectly clear effluent; can you explain that in any way?—No, I cannot explain that step by step, but it does not seem to me to be proof that the work is not anaërobic. That is all that I can say.

2711. I suppose the cellulose could not exist in the effluent in an altered form, and yet the effluent appear to the naked eye quite clear?—Oh yes, if cellulose were only in the form of some merely changed form such as sugar. Cellulose could very easily be converted into sugar by hydrolosis.

2712. True, but if you had pieces of paper going in at the top?—Yes.

2713. And a clear effluent coming out at the bottom?—Yes.

2714. That would be rather a rapid transformation, would it not?—Very rapid; it strikes me as extremely rapid.

2715. (*Professor Foster.*) There is a form of soluble cellulose, is there not?—Yes, there is a form of soluble cellulose, though I know nothing of it in connection with this.

2716. (*Sir Richard Thorne.*) You naturally confine yourself very largely to the bacteriological action upon sewage to-day; can you tell me whether in your opinion any chemical action goes on during the process of purification and filtration of sewage which is independent of the life-processes of micro-organisms?—Well, of course that is a question that is outside my immediate study; it is rather a question for a chemist; but I should say some changes must go on.

2717. Then it would not be, even in your own opinion, a purely bacteriological process?—Not necessarily so. At the same time I would point out, speaking generally of the importance of the bacteria in such processes, those cases where putrescible—exceedingly putrescible—substances are exposed to the action of air and to the environment generally, but keep free from bacteria, and they do not decompose.

2718. Then the main influence, I rather gather from that, would be a bacteriological and not a chemical one?—A bacteriological one, certainly.

2719. Have you any experience whatever as to the relative vitality of pathogenic and non-pathogenic organisms when they come into contact with each other; I mean do the non-pathogenic more easily destroy the pathogenic, or might the reverse possibly be the case?—That I cannot say.

2720. I rather gathered from one of your answers that a pathogenic property might be acquired by a non-pathogenic organism as the result of a single culture, is that your opinion?—I do not think I said that.

2721. Then I must have misunderstood you?—No, with cultivation generally the pathogenicity might increase.

2722. I thought I understood you to say that that would depend entirely upon the culture medium in which it was grown?—I do not think I said so. It would depend upon the conditions of culture and on the media, but more than that I should not like to say—that it was limited to any known number of cultures or any specific medium—but generally speaking these changes in pathogenicity

can be brought about by alterations in the conditions. I wish to speak quite generally with regard to pathogenic organisms.

2723. Speaking quite generally, is the process a slow one, do you think, and the result of many changes, or may the transformation from non-pathogenic to pathogenic take place with rapidity?—I should think with considerable rapidity sometimes.

2724. More rapidly than a gardener can transform the five-petal wild rose into a Gloire de Dijon?—Yes because we are concerned with changes which go by hours and days, whereas he is concerned with changes that take months and years.

2725. Then you are of opinion that it may be merely a matter of hours and days?—I think it may be a matter of hours and days.

2726. You were asked some question—I think it was by Professor Foster—as to the effect produced on pathogenic organisms on their reaching an ordinary watercourse. Should I be right in assuming in the case of a stream in its natural condition the change would be in the direction of an organism losing its pathogenic character, whereas it is the unnatural or polluted conditions that rather favour the transformation from non-pathogenic to pathogenic?—That a pathogenic organism passing from a material like sewage into water of a river would become less pathogenic is what I should expect, not the converse.

2727. Well, then, that being your view, could you form any general opinion as to whether it would be a safe or an unsafe principle to go on, to admit into a stream that which is possibly pathogenic, or potentially pathogenic, and then to rely upon the natural watercourse to destroy it?—I should say very unsafe, though the actual danger would depend upon many circumstances.

2748. I, of course, was referring to a stream which might be used for drinking purposes?—I have said nothing of the resistance of spores of the dormant forms, and it is not an uncommon event for an organism, which in a food material is fairly active, when it suddenly changes its condition, to be forced into a spore condition, and although if exposed to light as it passes down the river experiments show that it will be gradually destroyed, still how soon that will happen, or how muddy the river is, will affect the question, and I should think it would be an extremely dangerous thing to do in practice.

2749. And if spore formation took place, the organism would be much more difficult of destruction than if not, I suppose?—The danger might be increased very much.

2750. You were asked a question as to the influence of chemical trade refuse on bacterial processes, and you instanced the case of the alkalinity due to calcium carbonate destroying the acid result of the bacteriological action?—Yes.

2751. May I ask you if that acidity is not at times the ultimate and the final result of the life processes of organisms, and if so, is the mere destruction of it after the result has taken place necessarily harmful?—Not necessarily, perhaps, but the alteration of the medium in which the organisms were working might affect their method of working, or even their life.

2752. I am thinking of the fact that certain of these micro-organisms in their life processes do produce acids?—Yes.

2753. But it is generally, is it not, as the result of their actual death that the acids are formed?—I would rather put it this way: that the acids are produced during their lives, and as the amount of acid increases we often find that their action is inhibited—the life action is slower because there is too much acid there. There are many proofs of that. If we carefully remove the surplus acid as it forms, the bacterium can go on working a much longer time than it can if we allow the acid to accumulate, and I think in those cases it must be admitted that the acid is killing the bacteria, or bringing its action to a close.

2754. But the mere formation of acid might leave the bacterium, on which we are relying for the purification of sewage, still capable of performing its work?—If the acids do not accumulate beyond a certain point.

2755. The production of the acid is not necessarily what I might call a death-process of the organism?—Not at all; the production of the acid might be distinctly one of the acts of its life.

2756. (*Professor Foster.*) Is it not a very common feature of the action of these bacteria that an accumulation of their products, whatever they are, stops their action?—Whether acid or otherwise—yes.

2757. (*Sir Richard Thorne.*) Just now you were speaking of particles of a filter being coated with organisms, and, of course, this coating with organisms helps in the bacterial processes. Have you any opinion at all as to whether one or another material which can be coated in that way helps in the process or retards it? Is it merely a mechanical coating, and does it not matter what the material is, or does the material itself have an influence upon the power of the organisms to deal with sewage?—As an opinion, I think I should express it as follows: That if the material on which the coating is spread increases the surface—that is to say, if it is a coarser porous material—I should expect the action to be much greater than if it is a non-porous material with less surface; but if the substratum has any other importance than as a support to the bacterium, I know nothing about that, and it would be a question quite outside bacteriology.

2758. You could not say, then, whether pieces of polarite, for example, are any better than pieces of granite?—I do not know what polarite is.

2759. We have had different schemes of sewage disposal brought before us, in which some persons rely solely upon the action of anaërobic organisms, and others desire to rely solely upon the aërobic—should I be right in saying that the anaërobic processes, according to your view, give rise to putrefactive changes, and that the aërobic processes give rise to fermentative changes?—That is not quite what I mean to convey. It is true that in anaërobic processes there are often malodorous gases, and some attempt has been made to draw an artificial line between fermentations where malodorous gases were produced and fermentations where none such were produced; but no such line can be drawn.

2760. Then you have no knowledge at all as to whether an effluent would be likely to be worse from a simple anaërobic process as compared with a simple aërobic process?—Not without examination as to what was going on.

2761. You were good enough to give us an account of some of the constituents of sewage in the early part of your evidence in chief. Could you tell us what constituents are most difficult of being broken down into those more simple compounds that fit them as food for vegetables?—No. You see the conditions in which the nitrogenous materials exist are so vaguely put. One hears of albuminoids, and of other nitrogenous bodies, but I believe I am right in saying that there is no satisfactory definition of what is meant by those bodies, and how difficult a body is—how resistant it is to fermentation—is matter of experiment, and we must learn what the body is.

2762. And you have no experience, I think, as to any actual results as regards sewage?—No.

2763. I want once more to ask you about the influence of green mossy growths in relation to effluents. If you were to see, as some of us have seen, that in a certain process of sewage disposal a white glazed channel through which the effluent is flowing is coated for many yards thickly with an ordinary moss, should you be inclined to form any judgment as to the character of the effluent from that?—If it were really a moss I should expect the effluent to be very pure—that is to say, that of organic material it contained very little.

2764. (*Professor Foster.*) Can you conceive of the condition of an effluent in which there should be material in such a condition as to allow of plenty of free oxygen in the water, and yet of certain substances which might serve for the nutrition of the plant directly. We have evidence, have we not, that plants can absorb what used to be spoken of as humus?—That they can absorb it directly.

2765. Yes. You think not?—I think not.

2766. Or that they can live upon it, say?—They can live upon it.

2767. Well, that is what I mean really?—But the conditions are very remarkable.

2768. But is it quite impossible that an effluent should contain a certain quantity of organic matter which might be used very rapidly by the plant as food?—It is quite possible.

2769. And yet that material would not be in such a condition as to be continually taking oxygen from the water, and therefore to leave an inadequate quantity of free oxygen in the water?—I am afraid I am not quite clear as to the question.

2770. Might the effluent act as manure, and at the same time contain sufficient free oxygen for the oxygen needs of the plant?—I should think not.

2771. You think not?—If there is much of the sort of material we mean by "manure" in the water that is sur-

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rounding the plant, then I should expect that unless it is one of the very lowest blue-green algæ or Euglena, or one or two other very low forms, the conditions were very bad for the plant.

2772. Bad on account of the absence of free oxygen?—On account of the absence of free oxygen, and on account of the presence of certain poisonous substances.

2773. (*Sir Richard Thorne.*) But, on the other hand, the presence of a considerable amount of an ordinary green moss would, as a rough test, indicate to you that the effluent was of a certain degree of purity?—Yes, understanding that it is moss.

2774. Quite so?—The popular word "moss" conveys many ideas to people's minds. I am thinking of a moss—a real moss. There are very few mosses that will grow under water at all.

2775. I am speaking of "moss" in the popular sense; but in the cases I have in mind the moss would not grow under water, because the effluent is only passing over it for twenty minutes or half an hour in every period of six or seven hours?—Yes.

2776. And the greater part of the moss would even then be above the level of the effluent?—Yes, the effluent cannot affect it more than by ascending slightly by capillarity up the walls to its root hairs, and in that case it is not in contact with its general surface at all.

2777. (*Professor Foster.*) There it is taking its oxygen directly from the air?—It is taking its oxygen directly from the air in that case.

2778. And then the effluent might be a gentle manure?—Certainly, but that is another matter. I should like that to be quite clear—that if we are talking of a plant of that sort it is only on condition that its green parts are out of the effluent that I should imagine it to succeed at all. If its green parts are in the effluent, then the effluent cannot be very impure.

2779. All you could infer from the case suggested by Sir Richard Thorne is that the effluent is not bad enough to poison the plant?—That it is not bad enough to poison the plant.

2780. (*Sir Richard Thorne.*) You would not go further than that?—I would not go further than that.

2781. (*Chairman.*) I understand, then, that your opinion is that where there is symbiosis the aërobic organism may entirely envelop with its sphere of influence the anaërobic organism, and so protect it and keep it in existence?—Yes.

2782. Can the anaërobic organism return the compliment, and do the same for the aërobic organism?—No, because if it really is an anaërobic organism it could not withstand the oxygen.

2783. I mean where there is no oxygen, could an anaërobic organism surround with its sphere of influence an aërobic organism, and keep that in existence?—In that case the aërobic organism would suffer from the want of oxygen.

2784. Then the anaërobic organism could not do for the aërobic what the aërobic can do for the anaërobic?—No, the conditions could not be reversed.

2785. (*Professor Foster.*) There is no anaërobic organism capable of withstanding free oxygen?—Of withstanding free oxygen as far as I know.

2786. (*Chairman.*) And I understood you to say to Professor Foster that aërobic fermentation would be more rapid than anaërobic?—I should think aërobic fermentation is more rapid, but I know of no experiments. It rather seems to me a suggestion for an experimental inquiry.

2787. (*Professor Ramsay.*) Supposing an acid is produced after fermentation, and that acid accumulates in a fermenting liquor, the life of the organism is inhibited to some extent—it ceases action?—Yes.

2788. Is it necessary that it should be the acid that it has produced, or will any other acid produce the same effect. I will give you a specific instance to make the thing perfectly plain. When we ferment sugar we can make it give lactic acid under certain conditions, but the lactic acid increases to a certain extent the organisms. Supposing we were putting hydrochloric or any other acid in, would that have the same inhibitive effect?—Yes, if the quantity is at all comparable, I should say distinctly.

2789. I mean equivalent quantities?—

(*Professor Foster.*) What do you mean by equivalent quantities, because the organism there can stand a large quantity of nitric acid, but would be very soon killed by a very small quantity of hydrochloric?

2790. (*Professor Ramsay.*) Equally aërobic in both cases?—I cannot put it into numbers, but a very slight acid would be likely to bring it to a stop. In the lactic acid fermentation the practice is to put in some lime at the same time, and so keep down that acid. In any specific case it may be less on account of its being an acid qua acid than on account of its being a product of its own activity, which over and over again we find inhibits the action of a living organism.

(*Professor Foster.*) In the same way that sugar which in many respects except physically is an inert substance, will stop sugar producing ferment.

2791. (*Dr. Russell.*) I just wish to ask whether you have made any bacteriological study of sewage as it exists?—No special bacteriological study of sewage.

2792. Nor have you followed sewage through any of those processes which are supposed to clarify it bacteriologically?—No, none of the processes of dealing with sewage have I examined in detail.

Dr. German Sims Woodhead called; and Examined.

Dr. G. S. Woodhead.

2793. (*Chairman.*) You are Director of the Research Laboratories of the Conjoint Board of the Royal College of Physicians (Lond.) and Royal College of Surgeons (Eng.)?—I am.

2794. And author of "Practical Pathology," "Pathological Mycology," "Bacteria and their Products," and other works?—That is so.

2795. May I ask if you have studied the processes involved in the disintegration and oxidation of sewage, and have had any experience of the work done by bacteriological filter beds?—Yes, I have had some experience of these processes. For the last five or six years I have taken great interest in the question of bacteriolysis, and recently, or within the last two or three years, I have had opportunities of examining somewhat carefully several of the sewage installations, especially those erected for experimental purposes that have been constructed in various parts of the country.

2796. And may I ask what data you collected in connection with the question?—Well, I think the most important data are those collected at Exeter, and some facts connected with the Sutton filters, on Mr. Dibdin's advice, and a number of facts connected with Mr. Scott Moncreiff's filters. Those who have charge of these filters have been very kind in allowing me to examine from time to time the sewage before and during the process of treatment—the effluents at various stages—and I have a number of facts bearing on certain points in connection with these filters.

2797. Could you tell us generally what part bacteria play in carrying on the work?—Well, I think they play two very important parts perfectly distinct, and occurring at entirely different stages of the process of disintegration. From all that I have seen—and I have now examined a number of those filters—six or eight—I have come to the conclusion that there are two distinct processes. Of course, that is generally accepted, but it is not so generally accepted that these must be kept perfectly separate. There is an anaerobic change in which we have what corresponds to, what are usually spoken of, as putrefactive processes, and secondly we have the aërobic changes, which correspond, of course, to what is known as nitrification. In connection with disintegration of the crude sewage material and nitrification or oxidation of the products we have, in carrying on our experiments, taken two products as indicating the changes that were going on in the various filter beds. In the anaërobic filters we have taken the amount of the ammonia formed, and the presence of certain anaërobic organisms as a measure of the disintegrative change that is going on, and we find that the production of ammonia—of course, there are some other substances, but we have taken this as the really important one, along with the amount of peptonisation or digestion, by which the solids of the sewage are thrown into solution—gives an indication of the work that is being done in an anaërobic bed. In the aërobic bed we have taken the nitrification—that is, the production of nitrates—as the index of what is there going on. We have, of course, always examined at the

same time both filter and the effluent for aërobic organisms, and we find that the two sets of conditions run parallel with one another; if you have a large number of anaërobic organisms—given a sufficient quantity of sewage, or a sufficiently strong sewage—you will obtain a considerable quantity of ammonia; if, on the other hand, you have a large number of aërobic organisms, that is, organisms multiplying rapidly, and if there is plenty of oxygen present, you have a considerable proportion of nitrates formed. But wherever these two processes are too mixed up, even though the organisms can live to a certain extent side by side, it is found that the rate at which the individual process proceeds is to a certain extent interfered with. You have the series of changes, and the same ultimate results, but they do not go on so rapidly as when you can keep the two sets of organisms almost distinct. Of course, they can never be kept, so far as we can see, perfectly distinct, but it is possible to obtain a high degree of anaërobic change, and a high degree of aërobic change by controlling and modifying the conditions under which the sewage is broken down.

2798. Then you draw a sharp line of distinction between the work done by the anaërobic and the aërobic organisms?—A perfectly sharp line.

2799. And you consider it important that these two processes should be kept as separate as possible?—I do.

2800. Speaking generally, how do the anaërobic organisms act?—The appear to do a great deal of work by the use of a small amount of energy, because they break up, they wrench apart, the more highly-organised products of life, and so produce unstable substances that are readily attacked, especially by oxygen. They stir things up, as it were, effect a revolution, and then, whilst the resulting materials are in an unstable or nascent condition, they can be readily acted upon by oxygen. I think that that is the part that they play in these anaërobic beds. One or two molecules of oxygen or hydrogen, nitrogen, or carbon are snatched from a large and complex molecular group and this group is left in a very unstable condition or in the form of a number of rearranged and profoundly altered molecules, many of which readily undergo oxidation. There are certain organisms, especially those which attack cellulose, that appear to act almost entirely in the absence of free oxygen.

2801. And how do the aërobic organisms act?—Apparently in somewhat the same way, but being able to grow in the presence of oxygen, the conditions for oxidation are more favourable. There is a kind of nascent condition set up amongst the breaking-down substances, the oxygen attacks the gases as they are being set free before they have time to get into a stable form, and as the aërobic organisms grow readily in the presence of oxygen, and as oxygen is necessary for the oxidation of these various substances formed, the conditions go on more favourably—not perhaps entirely because of the action of the micro-organism, but because the micro-organism is able to grow in the presence of oxygen—that is, under conditions most favourable for the oxidation of the substances set free.

2802. Have you any evidence that you could give us in support of these statements?—I have certain evidence which I might bring forward just now, not all the result of complete experiments, whilst some of them, of course, have been published before, but they have a very distinct bearing on the question. If you will allow me, I will give one or two of them. I will first take the Claybury filters, which were erected by Mr. Dibdin, or under his supervision, at the Claybury Asylum. I may say that two samples of raw sewage were taken from the tanks. Sir Edward Frankland examined these sewages chemically, and I examined them bacteriologically. I found that in those sewages in which anaërobic-organisms were most numerous—that is, those taken from the deeper parts of the filters, because in these filters one finds that at different depths there are very different conditions—the ammonia was always much greater in quantity; whilst, taking the sewage as it ran from the surface, that is, where aërobic organisms were present, and where there was, of course, a certain amount of oxygen, there were nitrates present. It was a rough experiment, but it was a very conclusive one, to my mind.

2803. (*Professor Foster.*) Might I ask, my lord, what kind of filters those were?—This was one of Mr. Dibdin's coke breeze filters.

2804. Filling from above downwards?—Filling from above downwards, yes. I have the analyses here, and also a series of experiments; but it is scarcely necessary to go into detail concerning them. I would simply say that from the notes of this observation there is no doubt in my mind that we had in this filter anaërobic organisms in large numbers, aërobic organisms near the surface in larger numbers than anaërobic organisms, and amongst both of these organisms which had a very great power of peptonising gelatine and also a power of setting free marsh gas from sugar, or possibly from cellulose, and ammonia from nitrogenous compounds. These are the principal facts that we re-obtained from this filter, and I came to the conclusion that in this case the smell that was sometimes present, was due entirely to the changes that were taking place in the deeper portion—that is, the portion which was in the lower part of the filter, where rapid anaërobic changes were going on. The next series of experiments were those made on the Exeter filters, in which the results were very good. In these I wished to determine first of all whether any nitrates were formed, and, if so, in what proportion. In order to determine this we made cultures, without attempting to identify the individual organisms, first a series of aërobic cultures and then a series of anaërobic cultures from the various parts of the septic tank and from the filter beds. We separated eight groups of organisms, and then filtered some of the sewage through a Pasteur-Chamberland filter, so that it was absolutely germ-free; there was nothing left in it, at any rate, which we supposed would give rise to any change in the sewage—any change in the sewage, either chemical or biological. It remained absolutely germ-free. It was first distributed into a number of flasks and incubated for a considerable period in a warm chamber; then we inoculated a flask with one of the groups of organisms separated out, taking care, of course, to allow nothing to get in from the air. We found that any flask that was uninoculated remained in an absolutely stationary condition—there was no chemical change at all—but in those flasks that were inoculated with organisms, every one of those various groups, or almost all of them, gave rise to an increase in the amount of nitrate, accompanied by a most marked multiplication of the aërobic organisms. In the case of anaërobic organisms we were not able to determine that there was any increase in nitrates at all—we did not expect it, we expected rather a process of reduction, and therefore we were not very careful about our analyses—but certainly there appeared to be little or no nitrification. In the control flasks—of which we kept several—there was absolutely no change; the original figure remained for nitrogen as nitric acid 0·661 throughout the whole period. Then we examined the eight flasks inoculated with different groups of aërobic organisms. I may perhaps be allowed to give the percentages of rise of nitrogen as nitric acid. In the first group it was 114 per cent.—that is, it rose from 0·661 to 1·417 of nitrogen as nitric acid. In group No. 2 it was 109 per cent.—that is, it rose to 1·386. In Group 3 it was 95 per cent., having risen to 1·291. In Group 4 it was again 114 per cent., the rise being to 1·417. In Group 5 it was 147 per cent.; that was the highest we obtained, the rise being to 1·638. We now come to a group (No. 6) in which the nitrates were diminished in quantity to 0·3, but here we found that there was an excess of nitrites, perhaps due to reduction. For the estimation of the nitrites Dr. Rideal who made the estimation for us used simply a colour test, but, taking the standard as 10, we found that there was an excessive quantity of nitrites; so without attempting to give any numerical value we simply called it "excessive." Then in the next one (Group 7) there was only a slight rise. In Group 8 there was a slight fall, but here also there was a slight fall in the nitrites, so that one group of organisms brought about not only a fall in the nitrates but also a small fall in the nitrites. Then, taking the mixture of the three organisms which gave rise to the greatest nitrification, it was found that a group of these three gave only 119 per cent. increase—that is, 1·449 against 0·661; here again the nitrites appeared to be very much the same; perhaps there was a slight fall. Then, mixing all the organisms together, the whole of the groups that had been taken from the sewage, we found that there was still a very considerable increase in the amount of nitrogen as nitric acid—1·23 against 0·661, or about 86 per cent., the nitrites remaining very much the same. That was the first series of experiments made in order to determine whether these organisms taken from a filter in actual use, would bring about any increase in the quantity of nitrates present—that is, whether nitrification was going on or not. Since these observations were made quite a number of other experiments have been carried on on the same lines, but the results are not yet completely worked

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out. So much for the Exeter experiments. I have here a series of examinations of different effluents from another filter—an experimental filter at Ashtead, worked by Mr. Scott-Moncreiff. This was examined in order to determine if possible whether there was any great increase in the nitrates going on on a practical scale. We had already determined that the ammonia was present in the anaërobic tank in very large quantities. I have some statistics here, which I may mention afterwards. There was always a fall in what was spoken of, whatever it may be, as albuminoid ammonia, not a very satisfactory term. Still, we took it as being a substance commonly estimated. We found that in the effluent from the anaërobic tank there was always a considerable quantity of ammonia, but after passing it over a series of aërobic trays—filters—I suppose you understand the construction of the Scott-Moncreiff filters—of these various filters in fact?

2805. (*Chairman.*) I do not know the Scott-Moncreiff particularly. What is there special about it?—It differs from the others in that he separates his layers of coke. Instead of having a single layer of coke, we will say 4ft. thick, he has eight layers of coke. each of them 6in. thick, with an air space between each of them, so that the sewage in coming down passes through a layer of coke; it then splashes on to the next layer, splashes on to another, and passes through, and so the filter is divided really into six, eight, or whatever number of trays may be used.

2806. Then does he let his solids go on to the filter?—Solids all go into the anaërobic tank.

2807. Oh, he has got a tank, too?—Yes, he has an anaërobic tank. There are one or two points, I may say, that we have found in connection with these various filters, that may be of interest, but I will finish with these figures first. I have always taken the chlorine contents as being an index of the strength of the sewage, and I find that in this series it ranges between 7·6 and 10·7 per 100,000. In the first tray the free ammonia, on the first occasion on which it was examined, was 0·9 per 100,000. The albuminoid ammonia was 0·5, but there was a very considerable quantity of nitrogen as nitric acid—2·55. On two other occasions, on which this first tray was examined the ammonia was 4·2 and 4; of albuminoid ammonia there was 0·9 and 0·75; of nitrates, 2·78 and 3·809.

2808. (*Professor Foster.*) Excuse me, you say in the tray?—In the effluent as it came from the first tray.

2809. At the bottom of the filter?—Underneath the tray. We simply put in a dish and collect a certain quantity of the effluent. The effluent from the second tray contained 0·85 of free ammonia, 0·50 of albuminoid ammonia, and 3·209 of nitrogen as nitric acid. The effluent from the fourth tray contained 0·025 of free ammonia, 0·110 of albuminoid ammonia, and 4·77 of nitrogen as nitric acid. Of course, we did not quite expect these figures at first, we thought they must be too high, as it is often held that it is almost impossible to get more than five or six parts per 100,000 of nitrogen as nitric acid in any nitrification process—any ordinary nitrification process. We were somewhat upset at these figures, and thought there must be some mistake. We tested them, however, by various methods, and allowing for errors in these various methods, we came to the conclusion that they were substantially accurate figures. In the fifth tray we found 0·03 of free ammonia, 0·075 of albuminoid ammonia, and 6·25 of nitrogen as nitric acid In the effluent from the seventh tray on another date the figures were 0·03 of free ammonia, 0·09 of albuminoid ammonia, and 5·34 of nitrogen as nitric acid. From the eighth tray, that, of course, being the most important, the one that was looked upon as being the final effluent, we have a series of analyses of five different samples. The chlorine contents were 8·6, 8·9, 8·6, 10·7, and 8·8; free ammonia, 0·3, 0·2, 0·2, 0·2, and 1·27—there is a considerable rise on this occasion—and 0·04. The albuminoid ammonia was 0·09, 0·135, 0·110, 0·090, 0·100, and 0·100. And then the nitrates, 5·34, 7·4, 7·57, 7·57—a fortnight later—5·349, and 6·254. It was evident that a very considerable amount of oxidation, nitrification, was going on in the sewage as it passed through these trays; in fact, the figures here are very much higher than we have obtained in any other samples that we have ever taken, and I suppose we have examined some hundred samples altogether. Further, I have had the opportunity of examining samples of sewage and effluent from Caterham, where some new filter beds have been put up in connection with the Government barracks. I was specially anxious to examine these, and asked Mr. Moncreiff for permission to do this because these filters at Ashtead when we saw them had been running for some months, and, therefore, they had got into what was called the ripe condition, and I wanted, if possible, to follow out the ripening process, and to see whether there was any foundation for the statement that these filters act better when they are older than when they are freshly started. The chlorine content here was very, very high, as you will appreciate when I say that it runs from 12 per 100,000 to 20 per 100,000, a very high figure. There is one specimen in which it was 39·0 per 100,000. Of course, we did not take that as representing the amount of organic matter in the sewage. I should mention that I was very careful to get the amount of anaërobic change that was going on first, and taking the formation of ammonia as the index, we found that in the sewage, as it came from the drain, along which it had run for a very considerable distance, there was a very large quantity of ammonia present—18·8 parts per 100,000. This probably was mostly derived from the urea. Of course, in barracks the whole of the urine from a large number of soldiers came in the sewage, and it was concluded that the large quantity of ammonia present was due directly to the hydrolosis of the urea, that it was probably brought about by the ferment actually formed by the organisms, and that it took place almost immediately. Then, however, we found on taking the sewage from the anaërobic tank, that is, the tank containing the flints, which is a large tank to receive the sewage in the first instance, and allow it to rest as much as possible, the ammonia had risen, and I will give the results of three analyses—43 per 100,000, 41 per 100,000, and 35 from a third sample taken on a different date, so that here we had evidently a very good anaërobic change going on, if we are right in assuming that the ammonia formation gives us any indication as to the activity of this process. In another sample again we found 40 parts per 100,000. That is an average, taking these four analyses, of almost 40 per 100,000. Then in one sample, in fact in two of the samples, the albuminoid ammonia was not very high, that is, for a sewage; it was 1·5 in two of the samples, 4 in another, and was 6·5 in another. That is in material taken from the anaërobic tank, or from the sewer. The nitrates were very low. That was to be expected if there was anything in our previous experiments. The nitrates were 0·20, 0·20, 0·26, and 0·27; the total nitrogen (Kieldahl) in these samples was 47·5, 44·77, 33·6, 30·8, corresponding, of course, to the very high ammonias. The effluent passing over the bed before it had got ripe at all; in fact, one might almost say before there was any change affected by the filter except the mere mechanical and chemical change which may take place in sewage as it passes through an ordinary filter and is aërated was then examined. Here it was found that the ammonia had fallen only to 17·20, the albuminoid ammonia being 1·3 per 100,000. We have no analyses of the nitrates in this sample, nor did we estimate the total nitrogen. But a fortnight later another sample from the same effluent, that is after the experimental tray, was taken. The amount of chlorine was rather lower, and, therefore, we were dealing with a somewhat weaker sewage. The amount of free ammonia was 8·5; that is, the whole of it had certainly not evaporated in passing through this series of filtering trays; the albuminoid ammonia was 0·65, but the nitrates had risen to 3·49 parts per 100,000. That against 0·07, 0·06, 0·20, 0·20 in the other examinations. Then another sample was taken from a perfectly fresh filter. Here evaporation was going on to such an extent that the chlorine contents were very much higher, 39 per 100,000. Although there was this large amount of chlorine there were only 3·3 parts of free ammonia per 100,000. The nitrates were not high either, and in a series of other experiments on the early stages of the process, we found exactly the same throughout. There is practically no increase in the nitrates in the new bed. There is, however, always an increase of nitrates in a bed that has been running for some time. Those are the figures in connection with the Caterham filters. In addition to carrying on these experiments we have been separating the organisms from the sewage and from the effluent. This is a very long piece of work, and although we have not yet identified a large number of the organisms, and until we do that I do not intend to carry on any further experiments on their action on filtered sewage The experiments that we have carried out indicate that a large number of the organisms found in sewage exert a distinct influence in bringing about nitrification. That it is not confined apparently to the described nitrifying organisms but that any organisms which grow rapidly and break up sewage material have the power of inducing or commencing, as it were, this process of nitrification, if a sufficient quantity

of oxygen is alway present is evident. I think those are the principal points that come out of the experiments that so far we have carried on.

2810. (*Chairman.*) Do you think changes take place in the sewage while it is still in the drain?—Yes; probably symbiotic changes; that is where you have a moving fluid. Here you have a mixture of organisms; you have no differentiation into different groups, and it is probable that the urea fermenting organisms especially are present in large numbers, that they are forming their ferments, which act upon the urea almost as soon as it goes into the drain, indeed it is my opinion that a large amount of ammonia is present in solution in the liquid in the drain, before the sewage has passed through any special process at all.

2811. Then what would you consider the most important index of the activity of the aërobic bed or beds?—The formation of nitrates.

2812. Should you consider that the two processes, aërobic and anaërobic, are necessary for the achievement of the best results?—Yes, certainly.

2813. Will you tell us about the sewage purification works that you have visited and examined?—Well, in addition to those that I have mentioned I have seen those at West Bromwich, which were not particularly good at the time. I have seen those at Towcester and at Aylesbury, which were also not very good, especially as they were not being worked properly. For instance, at the Aylesbury installation which was carried on by Mr. Scott-Moncreiff, air was pumped as an experiment into what was practically an anaërobic chamber, and the result was, of course, that the anaërobic processes were weakened without in any way helping aërobic processes. Then again, at Towcester the sewage was first passed into a kind of cesspool in which undoubtedly anaërobic changes were going on. Then it was passed into a second anaërobic bed, and, perhaps, here the anaërobic changes were carried out more completely, perhaps even too far. Then instead of having some aeration or some special method for aeration, it was put into a stream in which water containing oxygen was coming, and, therefore, there was a certain amount of purification. But I do not think that it was going on under such good conditions as if some measures had been taken to allow a certain amount of aeration before it was thrown into the stream. Then I have had the opportunity of examining the Sutton filters, that is, the coke breeze filters, and of seeing the effluents. I was not able, at the time, as I was very busy, to take samples, but Mr. Chambers Smith promised, that if we wished to continue our investigations, a series of samples from the Sutton filters should be placed at our disposal. Then, of course, there are the Claybury filters, in which I think the two processes were being carried on side by side, the anaërobic and the aërobic, both imperfectly, or in an unbalanced condition, resulted in some "sickening."

2814. May I ask what you mean by "sickening"?—By "sickening"?

2815. Yes?—Well, it is really, I believe, a disturbance of the relation of the organisms one to the other, especially where you have symbiosis. Where you have two sets of organisms growing side by side they settle down, I believe, to a kind of equilibrium, and each does a certain amount of work, and so long as you keep the conditions exactly the same, supply them with a definite quantity of nutriment, and with a definite quantity of air, they will go on doing their work side by side, that is to say, the active splitting up by the anaërobic organisms and the oxidation by the aërobic organisms, but as soon as you upset these conditions, or alter them even very slightly, then the organisms, one or other, or both, appear to lose a certain amount of their power of doing work, and the filter is then said to "sicken." It is a somewhat technical term, but it is a very expressive one, and really indicates what is going on. For instance, I may mention that if you run one of the coke breeze filters, one of the Barking filters, for instance, filling it during a certain time, allowing it to stand for a certain time, and emptying it at a certain rate, there will come a period when you will get the very best work out of that filter that it is capable of doing. If, now, instead of emptying twice a day you empty three or four times a day, the amount of organic matter in the sewage remaining the same bulk for bulk, the filter immediately refuses to do its work, it is said to "sicken"; the anaërobic changes, of course, are interfered with, you have no corresponding or counterbalancing advantage by an immediate increase of the aërobic organisms, with the result that the filter does not do the work as well as it did under those conditions where it had got as it were into a condition of stable equilibrium.

2816. But would not all filters "sicken" in the course of time?—In the course of time?

2817. Yes?—They all ought to improve; they should all improve in time. A filter once started if it is properly worked should go on improving, and should be able to deal with a larger and larger quantity of sewage as time goes on. Of course, it would be necessary to make allowances for any mechanical filling of the filter with sand or clay or mud or anything of that kind, but, if proper precautions are taken to keep out the inorganic substances, the filter should go on working indefinitely after it is properly "balanced."

2818. What would you say were the special advantages of a biological filter?—The special advantages I think are that it may be made to work automatically; these filters are not dependent in any way upon attention, that is, if they are properly worked. Then, again, it is possible to get rid of almost the whole of the sludge, that is, all the organic sludge in a biological filter bed. Clay, sand, or anything of that kind cannot be dealt with in such a bed. That must be intercepted in some way, but organic matter in sewage should, in a properly constructed filter bed or a biological filter bed, be got rid of completely, because micro-organisms have the power of digesting practically all kinds of organic matter if you can only get the right organisms, and obtain the proper conditions in which these organisms may work.

2819. Would you tell us how the sludge difficulty is affected?—By the organisms digesting and getting into solution the organic sludge. Even the cellulose gives way. It is converted into more soluble substance. The various insoluble forms are gradually acted upon, the more soluble forms are acted upon more rapidly, and sugars, which are comparatively easily dealt with are produced. In addition there are, in sewage, the undigested nitrogenous substances, the substances from meat and so on; but these are all digested in time, in fact, some of them very rapidly. One knows that in the processes of the passage of food through the intestines a very large quantity of it is broken up. Just the same thing takes place in these tanks, the septic tank or the anaërobic chamber whatever it may be called. These apparently insoluble substances are rendered soluble by the action of the different micro-organisms, they are peptonised, or they are converted into sugar, or they are, some of them, broken down into various gases and into water, and similar more stable substances.

2820. Should you say that that system could be applied to trade refuse as well as sewage?—I should say so if they can arrange to have their acids and their alkalies fairly equally distributed. So far as concerns the various forms of refuse that I have seen, it is entirely a question of neutralising these trade effluents, whether from brewing or from tanning, or from alkali works, or from, say, the pickling liquids from galvanising tanks. They almost always neutralise one another, and the organic matter is treated or acted upon just as domestic organic matter is acted upon, so that if you can get the acids and the alkalies to balance equally or to leave a slight alkaline excess, there is no reason that trade effluents should not be treated by this method, and I believe that at Yeovil they have overcome many of their difficulties in connection with their treatment of trade effluents.

2821. Can you tell us whether further purification is likely to take place after the filtrate has left the filter beds?—Yes, I think that undoubtedly the filtrate—the filtered effluent—is in one of the best conditions for further purification if such further purification is necessary. If you throw it into a river, especially into a well oxygenated river, the process of oxidisation goes on until practically the whole of the material has disappeared, and if it is to be thrown on to land you have the whole of your substances in solution. You have a fair proportion of nitrates, which, of course, will be taken up very rapidly, and you have practically nothing that cannot be taken up by the soil, and nothing to clog the land, so that one of the great disadvantages of sewage farming, if it is thought necessary for the sake of what is in the sewage to throw it on to a farm, is done away with; there is nothing to clog the ground; everything is in solution, the form in which plant life will take it up most rapidly, and, therefore, I should consider it an advantage even from the point of view of sewage farming to first pass sewage through one of these biological beds, and certainly if the sewage is ultimately to be passed into the river or into the sea.

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2822. Have you much experience of sewage farms?—Well, I have not very much experience of sewage farms. The only one that I have seen very much of is Craigentinny, near Edinburgh, one, I believe, of the most successful; perhaps it is, therefore, scarcely a fair specimen to take, still I believe that some of the sewage farms have been fairly successful. I have also seen the Berlin farms, but have not studied them carefully.

2823. (*Sir Richard Thorne.*) You have given us experience in the main of the treatment of sewage, first anaërobic and then aërobic. Do you know any anaërobic process which in itself can produce an effluent that you would regard as satisfactory?—No.

2824. The aërobic must follow?—The aërobic must follow. That is as far as my experiences goes.

2825. In other words the splitting up, as one might term it, of the organic matter in the septic tank would not enable the organic matter to be dealt with in a flowing stream in such a way as not to do mischief?—It would depend upon the size of the stream.

2826. Yes, but speaking quite generally, you are of opinion that the aërobic filters should accompany the anaërobic septic tank?—Quite so. Excuse me a minute, unless, perhaps, you are going to throw it on to land or something of that kind.

2827. That would be aërobic to a certain extent?—That would be aërobic filtration, yes.

2828. Have you any experience whatever of aërobic filtration alone?—No, none at all.

2829. You have heard that there are filters I suppose in which aërobic action is relied upon alone?—Yes, but I do not think it is ever a pure aërobic change.

2830. That is what I was going to ask you. If the effluent be good, should you imply that there must be at some stage of the process the working of the anaërobic organisms as well?—Yes, I should say so practically. Of course, one can imagine conditions under which the aërobic disintegration would be possible, and as an experiment one knows that a breaking down by aërobic organisms only can occur; I think it is not only possible, but probable.

2831. Well now, take broad irrigation of sewage. What takes place there, aërobic or anaërobic, or both actions?—Both, decidedly.

2832. Both actions, decidedly?—Both actions, decidedly.

2833. The aërobic on the surface of the soil?—The aërobic on the surface of the soil, and the anaërobic deeper down in the soil.

2834. And the anaërobic in the depth?—Yes.

2835. Now, do you attach any importance to which of these processes takes precedence, the anaërobic or the aërobic?—Yes, ordinarily.

2836. The anaërobic should precede?—If we could take a sufficient area and take sufficient time, I do not think it would matter much which you placed first, in fact, it is quite possible that the aërobic might go first, but where the work has to be done rapidly, and where it has to be done in a limited space, I think the anaërobic change must come first, but must be stopped at a certain stage.

2837. When you were referring to Mr. Dibdin's filter you spoke of aërobic changes taking place on the surface of the filter, and anaërobic change taking place in the depth?—Taking place in the depth, yes.

2838. Now there the process is reversed?—Well, I do not think that the process is reversed; as a matter of fact, I think the anaërobic changes take place low down, and do not take place above, and the aërobic changes go on near the surface and not in the deeper layers of the bed. When the filter is full it is practically an anaërobic filter almost to the very surface, and it is only the quantity of oxygen that is in the pores of the "filter" that can do anything, and here it is rather an oxydation of the products already formed by the organisms while the filter is at rest; the oxygen is used up very rapidly indeed.

2839. Your contention would be that the anaërobic action took place when the filter was full?—Yes.

2840. And the aërobic during its emptying?—During its emptying.

2841. Now, you have spoken to us of biological filters. Is there any filter that is not biological?—Well, there are mechanical filters.

2842. What do you mean by a mechanical filter?—Simply a system in which by putting obstacles in the way of particulate matter you prevent its passing along with the fluid. In the case of these bacterial beds we are not dealing with matter by mere mechanical straining out. I think the term "filter" is a bad one as applied to these beds; we have rather, practically, an accumulation of micro-organisms into a small space, which do a certain amount of work on the material that is kept back for them by the mechanical part of the filter.

2843. Yes, but what mechanical filter that would deserve the name of a filter acts in any other way?—Well, they are numerous. For instance, the numerous filters on the market recommended for the filtration of water; of course, many of these do not deserve the name of filters, and a large number of filters are nothing but mechanical filters, and though they keep back large particles they let small particles through.

2844. You are speaking of water filters now?—Well, of any filter.

2845. Are they sold for sewage purposes then?—No, though the water is sometimes almost sewage when it comes from them.

2846. Do you know the Chorley filter?—The Chorley filter?

2847. Yes?—No, I do not know it at all.

2848. (*Major-General Carey.*) The tank effluent goes through the filter continuously in about 25 minutes?—Yes, or even less.

2849. Would you consider that a biological filter or a mechanical filter?—Well, I should want to examine the sewage before it went in and after it came out before I could express an opinion.

2850. Does the rapidity make any difference whether it is a biological or a mechanical filter?—Oh, not necessarily, because if you put the sewage through in small enough quantities and have a large number of organisms on your filtering medium you may pass it through rapidly, though in small quantities.

2851. I mean full quantities?—I should say it is more likely to be a mechanical filter, but I should not like to say without examining the sewage before it went through and after. It is only thus that one can tell; it is a question for direct experiment.

2852. (*Professor Foster.*) In these installations that you have visited, did you make any bacteriological examination of the final effluent?—Yes, always.

2853. Does that contain many organisms?—The number varies very greatly. It depends very greatly on the speed at which it comes from the filter, that is whether you take it at the beginning or at the end of the flow, whether there is a rush, a flood coming from the filter, or whether the water is simply trickling away. In a large rush or flood you get a large number of organisms; when the effluent is trickling away you find a comparatively small number of organisms, but you invariably get some.

2854. Are they different species of different kinds, or chiefly the same kind?—Oh, different species; of course, a comparatively small group. For instance, at Exeter we separated, I think, only seven or eight aërobic forms from the effluent.

2855. That is from the effluent of the filter?—Yes.

2856. The filtrate, as it is sometimes called?—The filtrate, yes.

2857. What were those forms?—Well, as I have said, I have not attempted yet to classify most of the forms, but some of them appear to belong to the potato bacillus group, others to the coli group, not always active on animals; some of the commoner water organisms are also present, which appear to be able to get through along with the sewage; this we did not expect.

2858. You did not recognise any distinct pathogenic organism?—None, except the bacillus coli.

2859. Then have you examined the interior of any of these filters?—Yes; that is, we have taken specimens from various depths.

2860. Have you determined the species of organisms there?—No, we have only grouped them roughly for experimental purposes.

2861. And you find that in the filter a very large number of them have nitrifying powers?—Yes, they have nitrifying powers.

2862. You have determined that experimentally?—Yes, especially in the case of those found near the surface; those deeper down have not the same nitrifying powers.

2863. Are they different forms?—Yes, they act differently certainly; some of them peptonise rapidly, but do not nitrify.

2864. Are they bacilli or cocci?—Principally bacilli, but cocci are not absent; the clostridium forms are very numerous in the anaërobic beds.

2865. Then you have examined the bacteria in the septic tank at Exeter, have you?—Yes.

2866. What forms did you find there?—A large number of anaërobic forms and a certain number of the aërobic forms that were found in the sewage—practically the same.

2867. In what condition were the aëroic forms—vigorous?—Fairly vigorous.

2868. Had you any reason to believe that there was any large formation of spores of the aërobic forms; did you make any observations?—No, we made no observations.

2869. To show if there would be spores of the aërobic forms there?—No; of course, the potato baccilus would form spores anywhere; they would form, I might say, almost under any conditions that would be met with in these filter beds.

2870. Then, speaking of nitrogenous matters, the change which takes place in proper treatment of sewage is, first, the bringing of the nitrogenous material into the condition of ammonia, and then the conversion of that ammonia into nitrates?—Yes, I think so from my experience.

2871. And do you think that the whole of the first series of changes leading to ammonia is necessarily anaërobic?—Well, I hold that they are principally anaërobic.

2872. But surely there are other forms, are there not—aërobic forms which can break down nitrogenous matters into ammonia?—Quite so.

2873. Then why should they not be active if they have the opportunity?—If they had the opportunity they might be active, but if you are breaking down nitrogenous matter into ammonia it would probably be found that the process would go further if there were plenty of oxygen present, and it is impossible to have vigorous aërobic organisms without the presence of plenty of free oxygen, and if you get as far as ammonia, and especially if you get this gas in the nascent condition, if you have plenty of oxygen present you are far more likely to get nitrites or nitrates through oxidation. If you cut off the oxygen, the condition under which anaërobic organisms can form plentifully, you are more likely to have the process stopping at the ammonia formation stage.

2874. Are there no organisms which act aërobically, and therefore which would perform their functions properly in a good supply of air and oxygen?—Certainly there are.

2875. Which bring down nitrogenous matters to the ammonia stage?—Yes.

2876. And to the ammonia stage only?—Quite so.

2877. Then why should they not?—For instance, urea.

2878. That is one, and possibly there are other ferments acting on other nitrogenous matters probably present in sewage?—Perhaps.

2879. Then if these are efficient, why should not the whole treatment of sewage be aërobic—aërobic as far as regards the change to ammonia, and aërobic as far as regards the subsequent change to nitrates?—Because most of the organisms that produce ammonia under these conditions require special substances on which to act.

2880. And these special substances are not present in sewage?—Are not always present in sewage. Of course you have urea.

2881. Do you know what are the nitrogenous substances present in sewage?—I do not know certainly.

2882. Does anybody know?—I do not think so, except as regards certain products of digestion.

2883. Then how do we know that the substances which are food for the aërobic organisms are not present in sewage?—Well, we know that there are no nitrates, for instance, in ordinary sewage, and very few nitrites, and these are the substances with which experiments have been made.

2884. No, but I am speaking of organisms which, acting aërobically, can break down albuminoid substances or like nitrogenous matter to the condition of ammonia; there are such organisms?—Certainly.

2885. Acting aërobically?—Yes.

2886. Then why should they not be efficient in the treatment of sewage?—Oh, I do not say they are not efficient; all I say is, we have no evidence that they are or that the substances they require are present. I should not like to say anything definite without having tried experiments with the separated organisms, and knowing the exact nature of the substances that are in the sewage. All I can say is, that we have no evidence of any such change in experiments carried on in my laboratory.

2887. Then in ordinary domestic sewage, at all events, putting aside the ammonia which comes from the urea, the nitrogenous constituents of the sewage are relatively small, are they not?—Comparatively small, yes.

2888. The greater bulk of the material of the sewage which has to be changed is non-nitrogenous—cellulose or the like?—Yes, non-nitrogenous.

2889. And that cellulose, of course, is not converted into ammonia; it is converted into carbonic di-oxide?—And carburetted hydrogen.

2890-1. That takes place by means of organisms which act aërobically or anaërobically?—Anaërobically, probably.

2892. Exclusively anaërobically?—Well, I should not like to say exclusively, but all the experience I have is that a great part of this is formed during the anaërobic stage of the breaking down process. Of course, you know at Exeter they have such a quantity of this gas that it may be burnt off from the anaërobic tank.

2893. You have no knowledge of aërobic organisms which can break up cellulose and like material?—No.

2894. Nevertheless, in the system which was described by Colonel Ducat, there, under conditions which were obviously aërobic, he states most distinctly that large masses of the sewage, obviously cellulose in character, or of like nature, does disappear through the action of the filter?—Yes.

2895. And, therefore, we may presume, must have been destroyed by aërobic organisms?—Yes, but it would not be in the form of marsh gas in that case, I think it is very probable, as I said before, that aërobic organisms can do almost anything.

2896. Then it is probable that there are aërobic organisms which can dispose of—let me use a general word—dispose of cellulose and allied matters?—Well, I should say it is possible, distinctly.

2897. But you do not know of any?—I do not know of any because I have not done any experiments in connection with that. All the cellulose experiments I have notes of so far are anaërobic, and resulted in the formation of marsh gas.

2898. When you were examining the septic tank at Exeter for bacteria—which you did, I think?—Yes.

2899. Did you come upon any other forms of life?—Oh, yes, there were a number of amœbaform bodies in the first part of the tank.

2900-1. What do you mean by the first part of the tank?—Just after the sewage came in. Then there were a number of flies which were supposed to live without oxygen. We had our doubts on that point.

2902. Forms apparently amœbiform?—Yes, quite so.

2903. Living apparently without oxygen, because there is no free oxygen in that tank, is there?—Well, we should have said there was no free oxygen, but having found these flies and these amœbiform organisms in the first part of the tank we came to the conclusion that some must be carried in in some way or other.

2904. You mean you found those just where the fluid was flowing in?—In the first part of the tank.

2905. I thought Dr. Rideal, in a statement which was put into our hands by Dr. Cameron, I think, described them as being in the sediment at the bottom of the tank?—He may have found them there. Was he referring to the flies?

2906-7. No, the amœbiform bodies?—Ah!

2908. And also a little eels, by which I suppose he meant nematoid, probably. Did you see any nematoids?—No, I did not see any at all.

2909. Were these large amœbæ or small?—Considerably larger than the white blood corpuscle.

2910. Larger than the white blood corpuscle?—Yes.

2911. And active?—No, not very active.

2912. They were alive?—They were alive there is no doubt.

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2913. And moving?—And moving.

2914. But sluggish?—I do not know what Dr. Rideal may have observed.

2915. Is the sewage exposed to air at all before it falls into that tank?—Well, it runs into a kind of hole or chamber.

2916. Into the grit chamber you mean?—No, a kind of trap or pool before it comes to the grit chamber.

2917. Does it get exposed to air there?—No, the grit chamber is inside the tank, and is formed by a submerged partition. There is a kind of space covered in, not covered in hermetically like the other, and there, of course, air gets in.

2918. You did not make any exact observations as to whether there was any free oxygen in the fluid of the septic tank?—No; the only reason we had for assuming that there must be some oxygen there was that we found these things living; the flies which were living on the surface of the fluid, or, rather, on the scum, were absolutely colourless, but they were very active, as we were able to see from the inspection chamber.

2919. Was that gas analysed?—Yes.

2920. What was its composition?—Dr. Rideal analysed it very carefully.

2921. Was there any free oxygen in it?—No, I do not think there was any. I believe I have got it here—the analysis of the gas. Of course, I did not do it myself, and perhaps it would be better to ask Dr. Rideal, but I think he gives it in print: "Two analyses of the gas obtained (1) from the slotted pipe, and (2) from below the surface of the liquid in the tank are given below; the second sample burnt freely and neither sample contained any oxygen:—

	Per Cent. 1.	By Volume. 2.
Carbonic acid - - -	0·3	0·6
Methane - - - - -	20·3	24·4
Hydrogen - - - - -	18·2	36·4
Nitrogen (by difference) - -	61·2	38·6
	100·0	100·0

2922. Did you break up any of the filters, or get into the interior of the filters so as to be able to ascertain exactly how the bacteria were placed in the filter? I mean were the fragments covered at all by any visible or appreciable layer?—Well, the harsh surface of the coke had gone. We dug down a couple of feet into the filters, in fact I have examined a great number of filters in that way, and there is generally a kind of rounding off of the harsh surface, and sometimes, but rarely when the filter is working well, even a slimy appearance on the coke.

2923. Did you examine that slime at all?—Yes, it consists almost entirely of micro-organisms.

2924. Of bacteria bacilli and cocci?—Particularly of bacteria and bacilli.

2925. In any particular condition, in zoogloea condition; anything like that?—Oh, yes, some of them were covered with zoogloea masses.

2926. A zoogloea mass?—Yes, some of them.

2927. (*Mr. Killick.*) I understand that you think the most favourable conditions for the purification of sewage is where the sewage is acted upon both by anaërobic and aërobic organisms?—First by anaërobic, secondly by aërobic, yes.

2928. You have found both kinds in some of the filters that you have examined?—Yes.

2929. Have those filters been of a particular construction?—I have found them of different kinds in every filter that I have examined. I have examined the coke breeze filters, the clay filters—the burnt clay filters. I have found them in the clinker ash filters, at Exeter; in the Scott-Moncrieff filters, in which you have masses, masses of flint in the first portion and coke in the second. I think those are the various forms that I have examined.

2930. Then if you find both kinds in the filter is it not possible that filtration alone is sufficient to purify ordinary sewage without being previously treated either in a precipitation tank or in a septic chamber?—I certainly think that no precipitation is necessary, but I think there is a distinct advantage in having first a septic chamber, or an anaërobic chamber, whichever form it takes. There is a distinct advantage in having that as a preliminary breaking-up of the sewage, as it were.

2931. You are aware of the tests that Sir Henry Roscoe applies, just as you may say shorthand notes of the effluents over which the Mersey and Irwell Board have jurisdiction, it is the albuminoid ammonia test and the absorption of oxygen from permanganate?—Well, the absorption of oxygen, I think, is a very good test. I am not so sure of the albuminoid ammonia test, because I think that it simply indicates the presence of a certain amount of organic matter in a somewhat indefinite or unknown form.

2932. The absorption of oxygen is a reliable test for general purposes?—For general purposes, yes, very reliable.

2933. Taking the two together they may be considered fairly accurate?—Well, in the case of sewage I should take rather the amount of nitrates present; I should prefer that to a record of the amount of albuminoid ammonia present, as an indication of the changes going on in sewage.

2934. (*Colonel Harding.*) You have told us your distinct opinion that it is advisable to use a septic tank in some form before biological filtration?—Yes.

2935. But I think you have not had much experience of the cases where double filtration has been in operation to crude sewage?—Yes, I have. I think the preliminary filter in most of these cases is nothing more than an anaërobic chamber.

2936. In that case you think that it acts anaërobically?—Yes.

2937. You have said, I think, that it acted anaërobically while it was full?—Yes.

2938. Aërobically while it was empty?—Well, it is rather that there is an oxidation of the products that had been formed during the anaërobic period; it is not so much, I believe, that it is a true aërobic process, but that you have an oxidation of the products of the anaërobic organisms formed during the anaërobic period.

2939. Then I take it that you do not deny that good results can be brought about by double filtration, but that you think in that case the first filter is acting anaërobically?—Anaërobically, yes.

2940. But surely in that case it might be possible to work that bed continuously, and not intermittently?—Certainly, but then there would be no oxidation of the products of decomposition in this filter. By any of those processes you can only take out in a single filter a certain proportion of the organic matter. If you can take out, say, 60 per cent. of that matter by your first filter you may take out 60 per cent. of what remains by means of a second process of filtration, and so on; you may go on until you get practically pure water, and, of course, in this case, three filters must be better than two.

2941. You would get increasingly good results?—Yes, that is, you take out a percentage of the organic matter by each filtration.

2942. But I was rather anxious to get at this point, whether if the first filter is to be considered, as working anaërobically it would not be possible, in your opinion, to work it continuously instead of intermittently? One does not see the necessity for aëration?—I think it is far better to work it continuously.

2943. Have you any experience—have you ever tried that continuous working?—That is the way the Scott-Moncreiff filter is working.

2944. But the Scott-Moncreiff filter follows a septic tank?—No, the Scott-Moncreiff filter has an anaërobic tank which, like the septic tank, is constructed for the purpose of getting an anaërobic change, and it is kept full constantly for that very purpose.

2945. Then you think that if the first filter, or calling it the name that you prefer—if the first bed were worked continuously similar results would be obtained from it as are obtained from the septic tank as used at Exeter?—Yes. In fact, the Scott-Moncreiff filter, taking that as an example, and as being somewhat different from the septic tank at Exeter, is simply a filter bed consisting of large flints, the flints being put there for the purpose of forming a large surface, on which the anaërobic organisms may grow, so that should there come a storm of rain, or a flood, to clear out the tank you still have your anaërobic organisms left to take on the work when the next batch of sewage is presented to them. The septic tank aims at

just the same thing; that is, getting a continuous anaërobic change. The only thing is that there, if the tank is washed out, there are fewer organisms left; there is not the extensive surface to which they may attach themselves, and on which they may grow, so that to a certain extent a fresh start has to be made.

2946. Does there not appear to be this advantage in double filtration, over filtration preceded by a septic tank, that if you get accumulations in that first stage of the process you are able to digest these accumulations by rest?—Well, really, there should be no accumulations in a septic tank, or in an anaërobic tank, because there is a large number of organisms which have the power, as I said, of breaking up nitrogenous matters, digesting them, or peptonising them, as it is called, just as we do in our own stomachs, and breaking up the cellulose and other parts of the solid material if it is left long enough. Settling to the bottom it may be three or four days, or a week, in being thrown into a solution, but when it is thrown into solution it passes over and is treated in the filter beds.

2947. Mr. Cameron, however, told us that there was a certain accumulation, not very serious, but still an accumulation, in his septic tank to the extent of about sixty-six cubic yards per annum?—Certainly.

2948. And that tank is, as you know, not a large one?—No.

2949. Now that is not possible to be cleared off otherwise than by removal, whereas if you have double filtration you can in the case of accumulations in the first filter digest them by letting that filter rest?—I think you will find that it amounts to very much the same thing. I believe that a great deal of the accumulation is inorganic matter, the silica and so on, on the plants—the clay which, of course, comes down in a state of very fine suspension and similar matter. I fancy that when they come to analyse the material at the bottom of the septic tank they will find it will consist very largely of inorganic matter, silica, etc. There is a certain quantity of silica in vegetable matter; that, of course, cannot be digested, but the vegetable matter itself will be, I think.

2950. Now, you told us of the presence of large numbers of micro-organisms in the sewage itself?—Yes.

2951. One has heard of the presence of millions in a cubic centimetre; that is quite possible?—That is quite possible; in fact, it is due to the presence of these organisms that the process of breaking down is going on.

2952. Their presence is a sign that there is work for them to do?—Yes.

2953. And one would expect to find in an effluent a smaller number of them, because there is less food and less work for them to accomplish?—Yes.

2954. You said also that a number of the micro-organisms were washed out of the filters more or less according to the rapidity of the flow?—Yes.

2955. Now we have to deal with the presence of these micro-organisms in the effluent. You do not consider their presence there as an objectionable feature in an effluent, do you?—Well, of course, it depends entirely on the nature of the organisms, and also on the number, and on the amount of organic matter that they have to deal with.

2956. I am not alluding, of course, to the presence of pathogenic organisms at all?—No.

2957. I am speaking simply of the presence of those organisms in the effluent which have been doing useful work in the filters?—Yes.

2958. Now, their presence in the effluent would be a guarantee of further purification, would it not?—I should say so, certainly.

2959. And therefore you would not consider their presence in the effluent as objectionable?—It depends whether the water is to be used for drinking purposes or not.

2960. Was not going to be used for drinking purposes?—Not for drinking purposes; then their presence would not be at all objectionable. It would be an advantage, because they would carry on the process of purification, and in connection with that one finds that a great number of the organisms that are found in the effluent disappear very rapidly as soon as they get into a well-oxygenated river; indeed, at Exeter we found that the effluent injected under the skin of a rabbit might cause very considerable swelling, or might even cause death; but taking the water half a mile down, which, of course, contains the sewage in an altered form—taking the water half a mile down it had practically not the slightest effect on the rabbit, so that these organisms that came out in the effluent, though not, perhaps, absolutely harmless, had disappeared half a mile down the river.

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2961. (*Chairman.*) Forgive me a moment, but surely at Exeter the effluent from Mr. Cameron's tank is the effluent of only a very small part of the town. Is it not the case that when you analyse the Exe water half a mile below the inflow of the effluent from the tank, you analyse the river water after it has received practically all the sewage of Exeter?—Yes, and some of the sewage was very offensive looking at one or two points.

2962. But you still found water in the Exe perfectly harmless to rabbits?—Perfectly harmless to rabbits, and that is probably the most severe test you can put it to.

2963. That is very remarkable, because the amount of sewage that comes from the town quite apart from the tank must be very large?—Well, you see, a large part of the sewage in the Exe will sediment out; the fæces and so on are broken down, and some of the matter sinks, whilst some of it is very rapidly transformed and unless you happen to get an actual particle in the water I do not suppose we should have anything that could affect animals; at least, that was our experience. I have a note of these experiments here. You know the points. "A series of experiments made with a view to determine the extent to which the various samples of effluent when alone and when mixed with the river retained their power of doing mischief was carried out for me for this inquiry by Dr. Cartwright Wood with samples of the tank effluent, or filtered effluent, of water taken from the river half-way down Belle Isle at Eveleigh, near the shore, and at St. James's Salmon Pool Weir. Duplicate sets of broth tubes were inoculated with samples of each of these materials. At the end of forty-eight hours one of these sets was taken from the incubator and 2 c.c. from each sample was injected subcutaneously into a rabbit and 2 c.c. into a guinea pig. That there was no great amount of morbific material in the water is proved by the fact that in not one single instance was there any indication of anything more than would be set up by the injection of a similar quantity of broth; when, however, the more delicate test of incubating for a much longer period (11 days), and then injecting the broth (*a*) into a vein of the rabbit (*b*) into the peritoneal cavity of the guinea-pig, it was found that by two samples out of four, *i.e.*, the tank effluent and the water taken from Belle Isle, death was induced in both rabbits and guinea-pigs, and when cultivations were made from the heart blood of the animals that succumbed, organisms were found; in the experiments with filtered effluent the results were negative, *i.e.*, death was not caused by the injected material. The water taken from the Salmon Pool Weir also contained so little morbific material of any kind that even with this severe test both animals remained alive and perfectly well." I may say these samples were taken at a time when the fluid was running very slowly; we did that purposely, because we did not wish to have a large rush of organisms; we wished to take it simply as it came from the filter and under the best conditions.

2964. Still, nobody would dream of thinking that that water was fit to drink half a mile below Exeter?—If it were filtered even fairly well, it might be used as far as the present conditions maintain, and no pathogenetic organisms are passing into it.

2965. I should be sorry to drink it?—So should I, but it would be really more from the sentimental point of view than from any actual harm that it would do at present. Having seen the Exe at Exeter, one would not drink the water at Salmon Pool Weir, and as a matter of principle, I should object to the use of water, into which ordinary sewage has recently been discharged, for drinking purposes.

2966. (*Colonel Harding.*) The object of sewage treatment is not, of course, generally to produce a water fit for drinking?—Certainly not.

2967. Though in some cases it may be necessary to turn sewage effluent into a stream which in some cases lower down may be used for drinking purposes?—Quite so.

2968. And in such cases, of course, a higher degree of purification, say, by triple filtration, would probably be necessary?—Quite so.

2969. Now, there are effluents which like those from chemical precipitation works may at first be without smell, and look fairly clear, which shortly afterwards putrefy. There are others, as I believe is often the case with these very biological filters, where the effluent

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though at first somewhat turbid or at least cloudy, purifies on exposure to the air or even on being bottled up?—That is the case.

2970. And becomes perfectly clear later on. Now, can you suggest to us any bacteriological investigation by which it would be possible to deduct in regard to an effluent its future possibilities?—Oh, I think it could be done quite easily by fermenting, or by adding different micro-organisms, and seeing whether you had ammonia, marsh gas, or similar substances forming. Wherever you have these formed in large quantities you will have putrefaction at a later period. That is, you will have an offensive sewage.

2971. Then, do I understand that you would fix this test by adding organisms to the effluent which were not in it already?—That might be done. But by simply puting the sewage into an incubator, and keeping it at the temperature of the body for a certain length of time you can tell whether the putrefactive process, that is, the coarse disintegration changes have taken place, simply by smelling the sewage; if there is no smell at the end of forty-eight hours or even a shorter period, you would say at once that that sewage had probably undergone the first decomposition, and all that is necessary now is to get oxidation completed, that is, it will not again be offensive. It depends to a great extent upon the amount of carbon, and, to a certain extent on the amount of sulphur present, and to a certain extent also on the amount of ammonia that is formed. If you can get offensive gases at a high temperature, that is, at the temperature of the body, then you know that the putrefactive changes as they are called, the coarse fermentation changes, are not yet complete, and they may occur later; if you supply plenty of oxygen you may never smell anything; that is, there may be no ordinary putrefaction going on. If, however, the conditions are unfavourable you may have a return to the putrefactive condition at any period, that is if a certain amount of the putrescible substances are left in.

2972. You then consider an incubator test of greater value for such a purpose than chemical analyses?—As a ready method of much greater value.

2973. Have you formed any opinion in regard to the value of noting the presence of some of the higher vegetable forms, such as algæ?—What they call the sewage fungi?

2974. Yes, that would be one of them?—Yes.

2975. Have you formed any opinion as to the value of oxidations of that kind in regard to sewage fungus, or in regard to green growth?—Well, I have no systematic observations. Of course, we have a number of records, but I have no systematic observations of my own on the subject.

2976. (*Dr. Russell.*) In those Claybury filters I think you said that the effluent from the anaërobic portion had a smell?—Yes, a slight smell.

2977. Did you detect any smell in connection with the anaërobic septic tank at Exeter?—There is always a slight smell; it is simply a question of degree. I mean, there are changes going on which must necessarily, if the changes are going on properly, lead to the production of a certain amount of smell. The thing is to get rid of the gases in some form in which they will not be offensive, or destroy them altogether.

2978. In either case, of course, you naturally would smell samples as a part of your examination, but in either case was there anything amounting to the likelihood of a public nuisance?—No, I do not think so in either of them.

2979. In those interesting experiments made with germ-free sewage, of course, the filtrate of a Pasteur-Chamberland filter ceases to be sewage in the practical sense in which sewage is before us?—Of course, it contains only the matters in solution; every solid particle is kept back, but you can get a very large quantity of matter into solution, and, therefore, it comes through the filter. It contains no particulate matter of any kind.

2980. But, still, you think it is sound to argue from those results as to the effect of those bacteria?—Oh, certainly.

2981. We have had a good deal of reference to-day to spores as explanation of some peculiarities in connection with the habits of these bacteriological filters, but can you tell me whether all the bacteria of sewage, as matter of fact, do produce spores?—No, a considerable number of them do not. Some of them form very resistant spores, but others appear to be killed off quite easily.

2982. But some of them do not form spores at all?—No, not so far as our knowledge goes, they are killed at a temperature which spores will withstand.

2983. You referred to a method of dealing with trade refuse. You said, on the principle by which you seemed to use these various sources of pollution to neutralise each other?—Yes.

2984. And I think you said they had overcome the difficulties very well at Yeovil?—So I believe.

2985. How did they do it?—Well, so far as I can learn—I only saw Mr. Armytage, the surveyor, and I was asking him about it—by carrying on their system essentially as they were carrying it on at Exeter. In the earlier experiments it seemed they departed somewhat from the plans laid down, and now by having a larger mixing tank or septic tank, so that there was a larger body of fluid passed through the filter, they have got better results.

2986. There was no such measure adopted as getting the manufacturer to store his refuse, and put it in in a regulated fashion?—I could not say that at all, because I have no knowledge of the exact details.

2987. (*Mr. Cotton.*) There is only one question I have to ask. In works on the Exeter system, if the effluent is to go into a stream, a small, not a very large stream, should it not be treated over again by further filtration, or be treated on land?—Well, of course, it depends on the strength of the sewage originally.

2988. I am talking of a stream that will probably be used for a water supply?—Oh, then certainly it should not be thrown in. I do not think that any sewage can be thrown without very careful treatment into any stream from which the water is to be drawn for drinking purposes; in fact, as a general principle, I should say that wherever water is to be taken from a stream within a certain distance no sewage should be put in; it should be carried down below. That should be a general principle. One may get perfect purification of sewage, and it may be mixed with such a large volume of water that it may be harmless. Still, there may come a time, an outbreak of typhoid, or something of that kind may occur, or something may go wrong with the filter works, and I should say that, as a general principle, wherever water is to be taken, from a small stream especially, that sewage should be passed through additional filters, or through land before it is allowed to go into the stream.

2989. (*Chairman.*) I do not know whether you could give an answer to a very general question, but do you believe that the filtrations through artificial filters can give quite as good results as filtration over land?—Well, I should say better results.

2990. Better?—I should say better results up to a certain point, in so far that you can concentrate the process as it were, and induce decomposition and nitrification, and in a shorter period; you can also control the changes better than you can in land filtration. The amount of land required is very large, it requires to be of a special character, and you are, as it were, to a certain extent dependent upon local conditions, whereas with a filter you can put down a definite area, you can give a definite depth, you can keep it working under special and well-controlled conditions, and, therefore, you know exactly what you are doing; whereas in the case of sewage farming the amount of rainfall, the kind of crops and so on, vary so much that you cannot come to any one set of conditions, in a filter you can either modify as required, or have, as it were, a cast-iron form, which will be applicable to all sewage of a definite character and composition.

2991. But do you think that with artificial filtration it is possible to get as good results as the very best results by land treatment?—Yes, if you carry it far enough, quite.

2992. If you carry it far enough?—Yes.

2993. I suppose you would say that the system of Mr. Scott-Moncreiff goes to show that a succession of filters improves with each filter—improves the filtrate?—Yes.

2994. And as regards any disease germs getting through, would you say they were equally likely to be destroyed by artificial filtration as by land treatment?—I should say quite as likely. Of course, we know that the typhoid germ, for instance, may live in sewage sodden soil for a considerable length of time.

2995. Yes?—It does not grow readily in water; in fact, I think it is open to question—a colleague of mine, Dr. Cartwright Wood, has been carrying on a series of experiments with typhoid bacillus on this point—it is open to question whether the typhoid bacillus multiplies

in water at all. It may remain alive in it for some time, but not for any very long period. It is stated that it can remain alive in soil. Well, the evidence on this point is a little conflicting at present, but there is no doubt that if you put broth on soil, that is, obtain an artificial condition, that the typhoid bacillus will remain alive for a considerable period. Whether it remains alive for anything like the same period in sewage-soaked soil, of course, has to be proved. I doubt this. It is probable, however, that it does remain alive much longer than it does in water. Then in middens and privies the typhoid bacillus has been proved to live for a very considerable period, but the conditions for multiplication in a filter are rather against the typhoid bacillus than in its favour, so that one would expect that pathogenic germs generally would be killed out more rapidly in a filter than in soil. Still, that is a matter on which I should not like to speak very definitely at present.

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ELEVENTH DAY.

Wednesday, 14*th December*, 1898.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.

Mr. F. J. WILLIS, *Secretary*.

Sir EDWARD FRANKLAND, K.C.B., called in; and Examined.

2996. (*Chairman.*) I think, Sir Edward, you were a member of the Royal Commission appointed in 1868 to inquire into the best means of preventing the pollution of rivers?—I was.

2997. Did the Commission visit much?—Yes, we visited all the chief manufacturing towns in Great Britain, and took samples of the discharges from factories, and especially the sewage discharges from different large towns, such as Manchester and Liverpool. We also examined a great number of effluents from sewage farms, and other processes by which the sewage was more or less purified.

2998. Did the Commission come to any general conclusions?—Yes. I may say that one of their general conclusions was that the great source of pollution of rivers was sewage proper as distinguished from manufacturing refuse.

2999. And did they form any opinion as to the components of the polluting matter?—Yes; they found that the polluting matter of town sewage and of imperfectly purified effluents was putrescible organic matter which, when discharged into streams of insufficient volume, caused these streams to become highly offensive, owing to the organic matter entering into putrefaction.

3000. Did you come to any general conclusion as to the proportions of liquid and solid polluting matter?—Yes; we went very thoroughly into that matter and found, somewhat to our surprise, that what appears to be most offensive to the eye in sewage was not really the chief polluting matter. What appears to the eye to be the polluting matter is the substance in suspension; but it is the organic matter in solution which chiefly contributes to the pollution of rivers. There is about one-seventh part of polluting matter in sewage in suspension, and the remaining six-sevenths are in solution, so that all remedies ought to be directed against the matter in solution rather than the matter in suspension. Moreover, the matters in suspension are comparatively easily got rid of by filtration and otherwise; but the matters in solution are more difficult to remove.

3001. Did you consider the question of defining in any way what a polluting liquid was?—Yes; we came to the conclusion that it was at all events very desirable, if not imperative, that there should be some such definition, because there is really no definite line of demarcation between more or less pure spring water on the one hand and the filthiest sewage on the other, and, therefore, we suggested that there should be a definition of polluting matter so as to form an arbitrary line of demarcation, at all events, between the two classes of liquids, what would be considered as comparatively pure, and what would be considered as polluting liquids, and we suggested a number of standards which have been since more or less acted upon in determining the character of effluents.

Sir E. Frankland, K.C.B. 14 Dec. 1898.

3002. It would be very interesting if you do not mind telling us what those standards were?—Yes. I have got a list of them here. These are standards, I should say, which define polluting liquids. They are as follow:—

(*a*) Any liquid containing, in suspension, more than three parts by weight of dry mineral matter, or one part by weight of dry organic matter in 100,000 parts by weight of the liquid.

(*b*) Any liquid containing, in solution, more than two parts by weight of organic carbon, or 0·3 part by weight of organic nitrogen in 100,000 parts by weight.

(*c*) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.

(*d*) Any liquid which contains, in solution, in 100,000 parts by weight, more than two parts by weight of any metal except calcium, magnesium, potassium, and sodium.

(*e*) Any liquid which, in 100,000 parts by weight, contains, whether in solution or suspension, in chemical combination or otherwise, more than ·05 part by weight of metallic arsenic.

(*f*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than one-part by weight of free chlorine.

(*g*) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.

(*h*) Any liquid possessing an acidity greater than that which is produced by adding two parts by weight of real muriatic acid to 1,000 parts by weight of distilled water.

(*i*) Any liquid possessing an alkalinity greater than that produced by adding one-part by weight of dry caustic soda to 1,000 parts by weight of distilled water.

In explanation of these standards, I should like to add that, in the first place, they represent in a concentrated form the experience of the Rivers Pollution Commissioners as to what is feasible in the purification of such liquids in the cases of discharges from factories, and also what is attainable and easily attainable in the case of the sewage of towns. They were framed with a very careful regard for the interests of the manufacturer, and so as not, in the terms of the Commission, to inflict any serious injury upon the manufacturers. In fact, the Commissioners kept much within their instructions, and believed that the adoption of no one of these standards would inflict any injury at all upon manufacturers. They had indeed every reason to conclude that their adoption would save the manufacturers of this country from inflicting considerable injury upon themselves; whilst, by preserv-

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ing the whole course of rivers in a comparatively clean and usable condition, they would tend powerfully to the extension of manufactures upon the banks of these streams. One of the most crying evils in the manufacturing districts is the want of clean water. It was at that time, and I have no doubt it is now still more so, and, therefore, every successful effort to make dirty water again usable is a direct gain to the manufacturer. On the assumption, therefore, that the discharge of strongly polluting water is to be forbidden by legislative enactment, I consider these standards of pollution as real friends to manufacturers, telling them in clear, intelligible, and definite terms what it is which they have to avoid, and shielding them, as the Alkali Act has so notoriously shielded the alkali manufacturers, from vexatious litigation. In explanation of these standards of pollution, the first three have reference to the discharges from the sewers of towns, and from calico print works, woollen works, and linen works, silk and paper works, and from skinneries and tanneries. All these kinds of pollution, all their polluting power, is due almost entirely to organic matter in solution; so that they are very similar in their character to town sewage itself—town sewage proper. The most important of the first three standards is the second, the enforcement of which indeed, so far as as nine-tenths of the polluted rivers in the kingdom are concerned, is absolutely essential to their purification. This standard refers to organic matter in solution, and is so low a standard that anything short of it would be mere mockery; in fact, I may say that the sewage of some towns, where there is an excessive water supply, is sometimes so dilute, in respect at all events to polluting organic matter in solution, as to come within this standard. The third standard might be abandoned without injury to health. It provides, in fact, only against nuisance to the eye. That is the standard of colour. That standard was at the time a good deal objected to, and I do not see much reason for enforcing it; the absence of colour makes rivers more pleasant to the eye, but does not contribute to good health in any way. The remaining standards have reference almost exclusively to chemical works. The fourth standard provides against the discharge into rivers of excessive quantities of salts of iron and manganese, which poison fish and render the river water unsuitable for other manufacturers. The next standard provides against the admission of arsenic in smaller quantities than was prevented by the previous one. The excessively poisonous character of this metal renders its exclusion from rivers as far as possible obviously desirable. The next standard is intended to exclude the discharge of bleaching liquors from chemical works, paper works and from bleach works generally. These liquors are peculiarly fatal to fish, but they are not prejudicial to health. In dealing with the sewage of towns, after an experience of thirty years as analyst to the Local Government Board, I do not remember a single case in which I have had to announce the infringement of any of the standards except the first and the second, but then I may mention that discharges from manufactories have not come much within my cognizance in that time. The samples sent to me by the Local Government Board and the inquiries the Board have instituted have been almost exclusively directed to the sewage of towns.

3003. Do you consider that in testing an effluent it is enough if you consider it by the light of these standards?—Yes; I believe that these standards would include all forms of pollution, and, in fact, I think if the second standard were enforced it would produce an enormous improvement in our river systems.

3004. And do you consider that the analytical processes which these standards require are simple and accurate?—Yes, they are all of them very simple. The second standard is generally considered to be the most difficult, but I have known several instances in which I have myself taught persons, almost ignorant of chemistry, to make the necessary analytical experiments, and in the course of from ten days to a fortnight they have been quite competent to make them.

3005. If an effluent was satisfactory according to all these standards, should you say that it might go into water that was going to be used for drinking purposes by human beings?—Yes, I should say so if it were sufficiently diluted by that water, and if the water were submitted to efficient sand filtration afterwards, but this latter would be essential.

3006. Should you say it might go into water which was used for drinking by milk cows?—Yes, I think so; that would, however, be without filtration.

3007. Yes.—There would be certainly a little more risk about that. I should not like to give a dogmatic opinion upon that point because I do not think there is sufficient experience of what would be produced in the case of cattle.

3008. (*Mr. Killick.*) In the final report of the Commission of 1868, Sir Edward, you expressed a very strong opinion that the proper way to treat river pollution was by dealing with the whole watershed of the river?—Yes; the Commissioners came, I think, to that conclusion that in order to have an efficient control over a river, the whole basin ought to be under the supervision of some one authority. I think some of us recommended a central authority, and others recommended a local authority.

3009. That is so. The Act of 1876 has been in force for twenty-two years; you have, I take it, a general knowledge of what has been done under that Act?—Yes. That Act did not go very far in the direction of the recommendations of our Commission, and did not adopt the standards, so that there have always been disputes as to whether any given discharge into a river was polluting or not, and obviously always will be so long as you have not a standard to go by.

3010. And after the twenty-two years' experience of this Act, are you still of opinion that the proper way to purify a river is to have one authority for the whole of the watershed?—Yes; I think so. And I think also our experience since the passing of that Act shows that it has been insufficient to prevent pollution. I do not see, judging by the eye, and also in some cases by analysis, that there has been any perceptible improvement effected in such rivers as the Irwell and the Irk, and the Medlock, for instance, in Manchester; they are all fearfully polluted still.

3011. Have you any knowledge of the watershed of the Mersey and Irwell since the formation of the Joint Committee?—No, very little except seeing it, of course, from the streets of Manchester and other places, and passing through the Ship Canal in summer.

3012. The standard that the Mersey and Irwell are endeavouring to enforce throughout the watershed is that the effluent shall not be liable to putrefaction at the place where it enters the stream? The rivers are somewhat better than when you inspected them; but not much better. Is not that a reasonable thing to begin with, that the effluent shall not be liable to putrefaction at the place where it enters the stream?—Oh yes, I think that certainly would be a very reasonable thing, but it is rather difficult to find out whether the effluent is liable to putrefaction. Effluents behave in a very mysterious way sometimes. Although they are highly polluting when they are turned into running water, they refuse to become offensive in bottle. I have had a good deal of experience of that. It is very difficult to determine whether a liquid is polluting or not by merely ascertaining whether it smells on being kept in a bottle at any favourable temperature even.

3013. Of course, it is necessary to know the condition of the stream into which the effluent is turned as well as the condition of the effluent?—Yes, I think no effluent ought to be objected to that is better than the stream into which it is being turned, and sometimes the rivers themselves are so polluted that an effluent without any treatment at all rather improves the river than otherwise.

3014. But do you not see the danger of that position, Sir Edward?—Yes, I do.

3015. If the effluent is not to be better than the stream into which it is turned you must begin the purification of a stream with the top pollution?—Yes.

3016. And you cannot proceed to deal with the second pollution until the top pollution is remedied?—I quite agree with that.

3017. Therefore, that suggestion is impracticable?—Oh, yes, I think it is only in very peculiar cases that the proposition I have just mentioned ought to be entertained at all. But I will mention one such case, that is St. Helens in Lancashire. Now, St. Helens is the great seat of the alkali manufacture by the Le Blanc process, and a good part of the town is even built upon alkali waste, and the river which runs through the town is polluted by the soakage from this alkali waste, so that

before it leaves the town it becomes strongly impregnated with sulphur compounds, and so long as the river is in that condition, I think it would be absurd to enforce standards which would be applicable to tolerably pure streams.

3018. Of course also the standards would vary whether the effluent were afterwards required for drinking purposes, and again on the other hand if it were turned into a tideway?—Yes, there ought to be more latitude certainly, when it is turned into a tideway.

3019. Now taking the object of the Mersey and Irwell to keep out effluents that are liable to putrefaction, might I ask your opinion of the tests which they use for the purpose of classification. One test is oxygen absorbed from permanganate of potash in four hours, the limit being one grain of oxygen per gallon; do you think that is a suitable test?—I think it is better than no test at all, certainly; but it is fallacious in several ways. There may be reducing agents present which would not be putrefactive in the stream, but which would absorb oxygen from the permanganate.

3020. But in practical work do you think that is liable to occur very often?—Yes, I think it would in the sewage of manufacturing towns as Birmingham and Wolverhampton, where large quantities of proto-salts of iron are discharged into the sewers.

3021. We have found one case in the Mersey and Irwell watershed—the case of Redditch—in the watershed there are four hundred manufacturers and eighty authorities. Then another test which is used is the albuminoid ammonia test, one-tenth of a grain per gallon; do you think that is of any value?—I do not think that is of any value at all—the albuminoid ammonia test—because it yields such very different results with different organic compounds. For instance, it gives no albuminoid ammonia at all, with urea which is the chief constituent of urine.

3022. Can you suggest any tests that would be better for the purpose of a river's board so as to keep out liquors liable to putrefaction?—Well, the test that I have always employed myself now for thirty years, and am continually employing, is that mentioned in the second of these standards—the determination of organic carbon and organic nitrogen. That is accomplished by evaporating a small quantity of the effluent—one or two hundred cubic centimetres to dryness in a glass basin, mixing the residue with oxide of copper, and burning it in a glass tube, the gases being collected and the quantity of carbonic acid and nitrogen evolved in the combustion measured.

3023. (*Professor Foster.*) Am I right, Sir Edward, in thinking that you introduced the term albuminoid ammonia?—No.

3024. Who did introduce the term?—It was Mr. Wanklyn, the analytical chemist, who introduced that term, and introduced the process, and it is no doubt very largely used by public analysts in roughly determining the amount of organic matter that is present in drinking water.

3025. What is supposed to be the real meaning of the term?—The real meaning of the term is supposed to be this, that all polluting matter is albumen, or of an albuminous nature, and that this yields a definite quantity of ammonia when it is treated with permanganate of potash and heated. But there are many other things besides albumen which yield this so-called albuminoid ammonia.

3026. Which yield ammonia treated by Wanklyn's process?—Yes, I may mention peaty matter. Peat which is thousands of years old is about the last substance which you would expect to contain albumen, and yet it yields a particularly large quantity of albuminoid ammonia. Hence a very peaty water which would not offend any of the standards except perhaps that of colour would be very strongly condemned by the albuminoid ammonia process.

3027. (*Professor Ramsay.*) The constituents of the peat effluent I suppose are harmless; the brown colour in peaty water is of no harm?—Oh, no; that, I think, we cannot consider to be harmful, because it is inevitable in mountain rivers in flood.

3028. (*Professor Foster.*) And does not putrefy under the action of the ordinary organisms which do cause putrefaction in albuminous compounds?—No, it never putrefies.

3029. And, therefore, never gives rise to offensive or poisonous results?—No, never.

3030. By polluting matter in a sewage I suppose you simply mean organic matter, or do you draw a distinction between organic matter and polluting organic matter?—Yes, I should draw a distinction certainly between polluting organic matter, and non-polluting organic matter, and peaty water would, I should consider, be non-polluting; but I have never found any stream, however peaty; that would infringe the second standard I was very careful to ascertain that before proposing that standard.

3031. But in ordinary sewage where you have not any peaty matter?—Yes, I consider in ordinary sewage all the organic matter present is polluting.

3032. And the suspended organic matter is in process of the flow of the sewage from time to time being converted into dissolved organic matter?—Yes, probably some part of it at all events, it is deposited in the stiller reaches of rivers usually, and then enters into putrefaction there, and rises to the surface very often in large pieces floated up by the putrefactive gases that are disengaged. I do not think we have any evidence that it enters into solution; but it is not at all improbable that some of it does.

3033. (*Professor Ramsay.*) How long did the 1868 Commission sit, Sir Edward?—Six years.

3034. And during that time had you a laboratory making experiments?—Yes, we had a very well equipped laboratory in Victoria Street, with three or four assistants continually at work during the whole time.

3035. Investigating the waters from a drinking point of view, or from a sewage point of view, or both?—Mostly from a sewage point of view, although at the same time drinking waters were sent there for examination by the Local Government Board. But the chief work of the laboratory was the investigation of those samples that were continually sent up by the Commissioners, and also the investigation of processes that were supposed to be available for the purification of polluting matters. A great deal of time was spent in investigating such processes as intermittent filtration, for instance, and broad irrigation, as used on sewage farms, and also processes for dealing with manufacturing refuse of various kinds. All those investigations were carried out there.

3036. And your processes for estimating carbon and nitrogen were elaborated there for the first time?—Yes; they were always carried out there from the first, but they had already been devised and used by me before the Commission was formed.

3037. I think Mr. Killick put a question to you as regards the turning of sewage into tidal estuaries; sewage need not be so carefully purified when it runs into an estuary as when it runs into a river. Are you aware that the effect of sewage running into an estuary is frequently to cause the growth of fungoid matter, which subsequently decomposes?—Oh, yes; it certainly does so, sometimes if there is not a sufficient current in the estuary to carry the matter rapidly out to sea.

3038. That would depend, I suppose, upon the shape and current of the river?—Yes, very much upon the current of the river and the length to which the tide would carry this sewage effluent up the river.

3039. May I ask, in the days when you carried on the laboratory in Victoria Street, was there any knowledge at all of bacteria?—No.

3040. That did not enter into your work, did it?—No, it did not. Of course, I had my suspicions in several cases, but they were mere suspicions. For instance, in intermittent filtration I came to the conclusion that there must be bacteria at work there, but, still, I never had any demonstration of that.

3041. I think you said, in your answer to one of the questions, that if it could be proved that an effluent would not undergo offensive decomposition when it entered a river that would be the best test for the purity of that effluent?—Yes, if you could apply the test in a trustworthy manner; but I have found that specimens of effluents put into bottles and kept in a warm room frequently did not become offensive, whereas when turned into a stream those effluents have rendered it very foul indeed.

3042. But do you not think that the difficulty could be got over by the light of our present knowledge, by submitting the effluents to the action of a bacteria bed?—Yes; I think, probably, if it were inoculated with putrefying organisms that might possibly be a valuable test.

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3043. (*Professor Foster.*) I think, in answer to a question by the Chairman, you said that an effluent which satisfied conditions might be discharged into a river, and the water of that river used for drinking purposes, provided in the first place that there was adequate dilution, and in the second place that it was passed through a sand filter?—Yes; subject, I said, to efficient sand filtration, which means the removal of at least 99 per cent. of the microbes present in the raw river water.

3044. It was, then, for the removal of the microbes in the effluent?—Yes, that is so.

3045. And not of any substance in the effluents?—I mean the removal of the microbes in sand filtration when the water was going to be used for drinking.

3046. Yes; but the object of the sand filtration was to remove injurious microbes which might be present in the effluent, although the quantity of organic matter in the effluent was below, or satisfied, at all events, your standard?—Yes.

3047. The object of the sand filtration was not a further removal of the organic matter, but a catching of the microbes which might be present?—Quite so. In fact, sand filtration cannot remove more than a small proportion of the organic matter present in solution, but it arrests about 99 per cent. of the microbes present.

3048. It was with the microbes distinctly in view that you recommend this efficient sand filtration?—Yes, certainly. That has entirely altered our conceptions of water supplies since the cultivation of microbes has received practical application.

3049. (*Professor Ramsay.*) May I return to the point we were discussing, Sir Edward, namely, the fact that water which putrefies sometimes when it enters a stream does not putrefy or may not putrefy when it is kept in a bottle?—Yes.

3050. Probably, owing to the absence of the putrefying organisms?—No doubt that is the reason.

3051. I think you, in your 1868 report, stated that "if water contaminated with organic matter be perfectly excluded from the air in a carefully-stoppered bottle, the gradual diminution in the amount of dissolved oxygen indicates exactly the progress in the oxidation of the organic matter." That is, of course, on the assumption that the oxidation does go on in the bottle?—Yes; there is a certain action goes on in the bottle, no doubt, but it is not always attended with the production of offensive gases.

3052. Quite so, and I think you said also that atmospheric oxygen is not very active in this respect, but dissolved oxygen is?—Yes, dissolved oxygen is more active.

3053. Then you go on further to state the experiments that you carried out show that no sewage could be destroyed by such action within a week, and that the amount of carbonic acid dissolved in the water remained constant during that period?—Yes; you are quoting, I think, from——

3054. From a statement of Sir Henry Roscoe, which he has given in as his proposed evidence?—Yes; I think that is contained in one of our reports; one of the reports of the Rivers Pollution Commission. [*See* 6th Report of the Rivers Pollution Commission, pp. 137-8.]

3055. Yes, it is?—I made the experiment, I may mention, myself, but I cannot quite remember the details and the results at the present moment, but the result was, I think, that no amount of oxidation that was caused in that way could materially affect a sewage effluent.

3056. Yes?—Within a reasonable time.

3057. Quite so; but I suppose you would agree that it would be possible to oxidise a carbon compound without the production of carbonic acid?—Oh, certainly, some carbon compounds can be.

3058. The oxygen need not go so far as to produce carbonic acid?—No, but you must have the absorption of the oxygen contained in a liquid or dissolved in it.

3059. You are finally credited with the statement: "It would be safer to infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation?"—Yes, I still hold to that opinion.

3060. But you think, I suppose, that efficient filtration through bacteria beds in presence of plenty of oxygen might effect such destruction?—Certainly; if you remove the bacteria, the organic matter in solution, so far as our present knowledge goes, is not deleterious to health at all. It may be that subsequent investigations may show that ptomaines, or something deleterious of that kind, may be present, but there is no evidence of such a thing at present, and if you remove the microbes then you may drink pretty concentrated sewage effluent without injury to health, probably.

3061. Did you do any personal work on the nature of the albuminoid matter?—Not in the Rivers Commission Laboratory.

3062. I mean, in your long controversy with Wanklyn?—Yes; I did a good deal of work in the way of testing the albuminoid ammonia process upon various waters. Dr. Odling and myself, when analysing for the Duke of Richmond's Commission, the Metropolitan Water Commission, made a great number of experiments at that time, and the result was that we came to the conclusion that the albuminoid ammonia process was not trustworthy, but we applied it to all the waters, I believe, that were analysed for the Commission by us—Dr. Odling and myself.

3063. Did you attempt to apply it to any albuminoid compound that one can see?—Oh, certainly.

3064. In certain cases did you find destruction, and in other cases not?—In some cases we found one proportion of ammonia given off per unit of organic matter, and in others two or three times that amount, perhaps, or none at all, as in the case of urea.

3065. And have you ever noticed this—that mere evaporation with water is sufficient to decompose a certain amount of, probably, albuminoid matter, or at all events to cause ammonia to be evolved?—During the evaporation?

3066. Yes?—No, I have never noticed that in the case of drinking waters, at all events, and I do not know that I ever noticed it either in the case of sewage. I have not particularly studied that point with regard to sewage, but it certainly is not so with regard to water.

3067. The albuminoid ammonia is stable on evaporation to dryness?—Yes, the evaporation is conducted after the addition of sulphurous acid, which probably prevents any decomposition.

3068. Quite so; I had forgotten that?

3069. (*Major-General Carey.*) Land was recommended by the Royal Commission of 1868 as the best purifier of sewage then known, as the direct result of your laboratory experiments, was it not?—Yes, that was so, and not merely of our laboratory experiments, but from the practical application of the principle in the case of sewage farms. There were already at the time of this Commission many sewage farms in operation, and we studied the results there very carefully, and there were also one or two cases of the application of intermittent filtration, which was recommended to begin with in consequence of our laboratory experiments.

3070. Intermittent filtration of sewage through land came into use at Merthyr Tydvyl, did it not?—Yes, it did. Mr. Bailey Denton applied it there, according to our directions, and it was very successful. The result of the Merthyr Tydvyl purifying filters was that the sewage of three thousand people could be efficiently treated upon an acre of land—of suitable land—provided it were drained six feet deep.

3071. That proportion had to be modified considerably afterwards, had it not?—I do not think so.

3072. I mean purifying the sewage of a population of three thousand persons to the acre?—Oh, at Merthyr Tydvyl the intermittent filters were to a great extent abandoned afterwards because at the time they were first formed the Corporation had already bought a large quantity of land down the river and they thought it better to fertilise this land by the sewage, and, therefore, they adopted broad irrigation afterwards, but kept on these filters, supplying them with a smaller quantity of the sewage, and growing crops of cabbages and other vegetables upon them, but I do not think there was any modification as to the possibility of purifying the sewage of three thousand people.

3073. Practically that proportion has never been adopted in other places in the country. The proportion of 3,000 persons to the acre is a very high proportion, and was the result of laboratory experiments which were not found to work out in practice?—Well, I cannot recall to mind any case in which it failed, if the land was suitable. It could not answer of course upon unsuitable land, upon non-porous soil, but on a sandy or gravelly

soil, I believe that at least the sewage of 3,000 people could be treated successfully. Since that time, I ought to mention, there has been another process, and one only in which I, myself, have confidence for the purification of sewage, and that is the bacterial treatment of it in tanks. I have had some little experience of this process, and the results, so far as I have gone, show that it is capable of very efficient application to sewage.

3074. Without treatment on land?—Without any treatment upon land.

3075. (*Professor Ramsay.*) I forget if you treat your own sewage, do you, at your country house?—No.

3076. Only your water?—No; I am drained into the main drainage there.

3077. You soften your water, I think?—I soften my water. I have my own well in the upper greensand, and I soften the water.

3078. You do not otherwise purify the water except by softening?—No; except by softening.

3079. (*Major-General Carey.*) Are you referring to the sewage of any towns?—No; I am referring to the sewage of Sutton with regard to the bacterial treatment, that is where I made some experiments.

3080. At Sutton they have some twenty-four acres of land available?—Oh, yes. This process was only being carried out upon, I suppose, one-fourth or one-fifth of the sewage at the outside, the other was going upon the land as usual, but they were contemplating adopting it for the whole of the sewage. It was certainly a very striking result that I got there, and I visited the works myself, and took my own samples, so that there can be no doubt about it. The transfer of the sewage matter into nitrates went on to such an extent, that I should scarcely have deemed possible in so short a time, because the treatment did not take longer than about three or four hours.

3081. Then, do you consider that that recommendation of the Royal Commission of 1868 should be modified at present as to the use of land for the purification of sewage?—Yes, but I think where sufficient land is available, where land is available at a sufficiently cheap rate, I should still prefer the land treatment, because you utilise for the benefit of the community at large the fertilising constitutents of the sewage, and, of course, it is all lost by the septic treatment. That is an economical rather than a chemical question.

3082. Has the value of your process for ascertaining the organic part of nitrogen ever been called in question that you are aware of?—The value of it; no, I do not think the value of it has, but it has been complained of as being troublesome and costly. It requires rather costly apparatus. I mean you require about six or seven pounds of mercury, which costs 2s. or 3s. a pound. I do not mean for each analysis, that will last for years, of course, but in fitting up your laboratory for its operation, and you require a gas analysis apparatus and an arrangement for evaporating down these effluents in glass dishes for combustion. It is altogether a process which takes more time, there is no doubt, than the albuminoid ammonia process, or the oxygen absorbed process. They occupy at the outside three or four hours, whilst this combustion process cannot be well carried out without undue pressure of work in less than twenty-four hours or even forty-eight in the case of drinking water. But in the case of sewage, owing to the smaller quantity required to be evaporated it would be quite easy to carry it out within twenty-four hours, and, of course, several samples can be operated simultaneously.

3083. I understand you consider that process gives far more reliable results than either the albuminoid ammonia or the oxygen absorbed standards?—Yes, I do, and I think it is quite worth the additional trouble in getting the result.

3084. (*Colonel Harding.*) In regard to the three conditions that you have mentioned to us as being specially applicable to the sewage of towns I understand you to say that the third as to discoloration was not important?—It is of no importance as regards injury to health; it is of importance if you want to have a pleasant-looking stream.

3085. Then, in regard to the other two, *a* and *b*, you consider *b* by far the more important of the two?—Yes, I do, for the reason I have already assigned, that six-sevenths of the polluting matter in sewage is in solution, and that second standard is the one that is applicable to the polluting organic matter in solution, the first being for the polluting matter in suspension.

3086. Have you been able to form any opinion as to whether, part for part, matters in suspension are more likely than matters in solution to produce the results of putrefaction?—No; they are both liable to putrefy, but I look upon matters in solution as being the most serious part of the polluting matter, because they are more difficult to remove, more difficult to deal with, there are many simple ways of getting rid of the matters in suspension.

3087. Now, as to condition *b*. You lay down that certain proportions of organic carbon and organic nitrogen must not be exceeded. Does that include the estimation of the matters in suspension, as well as those in solution?—No; the matters in suspension are removed first by filtration before that second standard is applied.

3088. Then we are to understand that that second standard applies to a sewage from which the solids in suspension have already been removed?—Yes, certainly.

3089. I believe it is somewhat usual in analysing an effluent to take that course, to, first of all, estimate the solids in suspension separately, and then deal chemically with the filtered effluent?—Certainly, that is always done in the case of a raw sewage, but very rarely in the case of sewage effluents, because practically the whole of the suspended matter in the very worst processes is removed. The effluent is still what we term turbid, that is, much too muddy to be used as drinking water for instance, but the amount of suspended matter present is not sufficient to require an estimation of it.

3090. Then there might be considerable turbidity without there being present a large quantity of matters in suspension?—Certainly.

3091. In answer to my colleague, Mr. Killick's question as to the value of oxygen absorbed, you said that it was a test which was better than none at all?—Yes.

3092. In regard to the albuminoid ammonia, you scarcely went so far?—No, I should greatly prefer the oxygen absorbed process to the albuminoid ammonia.

3093. In regard to the albuminoid ammonia, you thought that it might in some respects be unfavourable to an effluent, because certain matters—for instance, peaty matters—might give a greater result in albuminoid ammonia without being really injurious in any way to health?—Yes.

3094. And on the other hand, certain matters, like urea, might not give results in albuminoid ammonia and yet be objectionable?—Yes, that is so. It is an uncertain process, and you cannot trust implicitly the results.

3095. But apart from this uncertainty, Sir Edward, do you not think that the albuminoid ammonia test bears a sort of general relation to the impurities of an effluent, just as the oxygen absorbed does?—Yes, if the effluents are of a tolerably constant composition it does, and so does the oxygen absorbed, but if the composition of the effluent, the constituents present change, then both those processes give a different result in reference to a unit of the polluting matter.

3096. What I wanted to get at was whether, although these two tests were not reliable in regard to accuracy, they might not form a sort of rough-and-ready way of estimating the chemical constitution of sewage effluents. For instance, Sir Edward, I am not a chemist, of course, but I have had a good deal to do lately with the practical examination of these matters, and to take a recent instance, I found that the results in albuminoid ammonia given by crude sewage, including the matters in suspension, were ·85?—·85.

3097. Yes; when they had been filtered so as to eliminate the matters in suspension the results in albuminoid ammonia were ·45. Then, finally, when this effluent had been treated by intermittent filtration the effluent gave ·08. Now, there appears to be a certain relation between the albuminoid ammonia results and the impurities in these three liquids. Do you think that was utterly unreliable?—I think the first two must have been fallacious, because, according to these two estimations, the matters in suspension must have contained as much polluting material, as much albumen, as the clear liquid, because, you see, the albuminoid process showed ·8 in the case of the sewage with the suspended matter, and only ·4 when the suspended matter had been removed. I think that must be a fallacious result, but the final one I think would enable you to say that that liquid was quite fit to go into a stream. What I wish to say is that I consider both these processes are untrustworthy, when

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used with a mixture of so many and various substances as you have in the sewage of a town.

3098. (*Professor Ramsay.*) Referring to the question of permanganate again, the oxygen absorbed and albuminoid ammonia, do you not consider that they are really two methods of applying the same test?—Yes, I think they are very much.

3099. Very much?—But the albuminoid ammonia is the more uncertain of the two, I think, on account of the very different amounts of ammonia yielded by different organic substances, but they both consist in subjecting the organic matter to the oxidising effect of permanganate of potash.

3100. (*Chairman.*) I think you said that you had seen a little of the results of some of the new systems of artificial filtration. Have you made any analyses of those results?—Do you mean, my Lord, the results at Sutton, that I spoke of just now.

3101. You have made analyses of them?—Yes, I have.

3102. You have?—Yes, I have very carefully.

3103. And at any other place besides Sutton?—At some lunatic asylum, the name of which I forget, but there only one septic tank was used, and that certainly was not successful. The effluent from that was quite as bad as the raw sewage that was going into it. At Sutton two tanks were used, and the effluent from the first was carried into a second tank, containing coke breeze, and it was in that tank that the chief purification took place, and the degree of purification was very remarkable.

3104. And you would be generally disposed to hope that satisfactory systems of artificial filtration might be discovered?—Yes, at all events of treatment in tanks, in septic tanks in that way. I think that is a process which looks very hopeful at present.

3105. (*Major-General Carey.*) But that is quite distinct from the Sutton system, where there is no septic tank. The Sutton system, of course, depends entirely upon filtration through filters, through a coarse and fine filter?—In the process that I investigated there—the experimental process that was going on upon a large scale—the sewage was submitted to septic influences in two separate tanks.

3106. (*Professor Foster.*) Excuse me, Sir Edward, you are speaking of Mr. Dibdin's second filter as the septic tank?—Yes. It is there, I presume that the aërobic microbes performed their work, whereas in the first tank the anaërobic microbes performed their work.

Mr. W. D. Scott Moncreiff, called in; and Examined.

Mr. W. D. Scott Moncreiff.

3106*. (*Chairman.*) You are, Mr. Scott Moncreiff, an engineer of many years' experience, and were Keith Prizeman in 1874, elected a Member of the Institution of Mechanical Engineers in 1884, and of the Sanitary Institute, 1888. You have contributed many papers on various engineering subjects, and have lectured on sanitation to the Royal Military School of Engineering, and are the author of a paper on "The Biolysis of Sewage," read at the recent Sanitary Congress held in Birmingham?—That is so.

3107. What experience have you had with regard to the subject matter of the present inquiry?—In the year 1891 the building of a new house in the country afforded me the opportunity for making experiments upon sewage purification upon a practical scale. I had long been convinced that nature was capable of dealing with the entire waste products from man and animals, and that it was only necessary to supplement her methods to enable her to deal with the special difficulties of the sewage problem without the use of chemicals.

3108. What led you to form this opinion?—There was no literature available at the time of which I speak—in 1891—or, at any rate, none to which I had access, but I had always been impressed with the rapid liquefaction of organic waste products in long lengths of sewers.

3109. Have you anything to say about the reports issued from time to time by the State Board of Health of Massachusetts?—I had not seen nor even heard of them until after I had constructed the apparatus for dealing with the sewage of my own house.

3110. After you had seen them, how did the information they contained bear upon your further experiments?—They were principally useful to me as confirming the results obtained by Warrington in his investigation on the action of micro-organisms in the upper layers of cultivated soils, and they proved that somewhat similar processes were at work in the case of sewage passing downward through properly aërated filters.

3111. Do you think the Massachusetts experiments exhaustive of all the problems before us in England?—My view of the Massachusetts experiments is that they were only applicable to the case of very diluted sewage or to sewage from which the grosser organic matters in suspension had been kept back, because ordinary sewage would have clogged the upper surfaces of the filters so that they would have ceased to act altogether.

3112. Then in your view the experiments could not embrace the whole of the problems that we have to deal with on this Commission?—I think not. I had assumed that nature was capable of dealing with all parts of the problem, and obviously liquefaction of the suspended organic matters would have to be a condition precedent to any treatment in downward filters. That is to say, if nature was to be the sole agent independent of chemicals.

3113. Now will you explain the nature of your own apparatus?—The apparatus as it was put up at my own house, and which has not been altered, is shown on the diagram on the wall. The apparatus at Ashtead is shown on the accompanying drawing. The sewage enters and discharges as shown by the arrows. It passes through the channel and beneath the grating shown in the sectional elevation and rises to the level of the outlet pipes where it overflows. Instead of flints, coke, and gravel, flints alone have been found to give the best results.

3114. (*Professor Foster.*) That is a cross section, is it?—*B* is a cross section. Rising through this grating there is a complete moving away of the products of fermentation from the incoming sewage. Assuming that the bacterial action amongst the flints is zonal in its character, that is to say, that there are different conditions in regard to aëration, in the lower stages from those higher up amongst the flints then aërobic organisms would always be moving in the direction of the fresh food supply. On the other hand, as they rob the sewage of oxygen you get a zone in which the oxygen becomes totally consumed. Supposing the conditions remained quite regular you would have zones becoming more and more anaërobic in character towards the top of the flints. The advantage of this apparatus arose from the fact that there is no part of it unaffected by the general movement of the sewage, so that if the conditions remain constant you have zones representing different stages of decomposition each having organisms best capable of carrying on the work.

3115. That is filled with stone?—Large stones; no attempt at filtration.

3116. (*Professor Ramsay.*) What depth, please?—This was about twenty inches.

3117. (*Mr. Killick.*) Flints, I think you said?—Flints, yes, I tried various materials, but flints were the best.

3118. (*Professor Foster.*) Because they were the most stable; they did not change?—Well, at a very early period in these experiments I was able to point out the advantages and disadvantages of coke, for instance in the case of a water-logged filter.

3119. But your object is to get your material inert. I mean in inert pieces?—Quite so, but it would not be altogether inert in the case of various substances like coke, because there is no doubt coke would become saturated with the products of the organisms, and you would get toxic conditions arising which would be unfavourable to bacterial activity. I gave up coke because I had every reason to suppose that it became more saturated than a solid material, like flints, which simply formed a surface for the organismas to work upon. The effluent from this process was invariably without oxygen; there was no free oxygen available at all, so that the process was practically anaërobic, although it had an open surface at the top. This apparatus was so simple that it led everyone to suppose that choking would take place as a matter of course. The channel beneath the grating was only about five cubic feet altogether. Now, no choking took place, and a gradual improvement went on in the effluent. At the end of a year I found the effluent almost

sparkling as it came away, and then I made up my mind that I had really provided some very material condition of success. I found by experiment that the effluent was capable of breaking down fœcal matter into a granular mass in about seven minutes.

3120. At what temperature?—At the ordinary temperature of the sewage. Making the same experiment with tap water, I found there was very little change in twenty-four hours. It was not reasonable to suppose that this active condition could arise from the work of the organisms themselves. They could not have propagated at anything like that rate, and I therefore came to the conclusion that there was a very active agent in the enzymes of this anaërobic fermentation.

3121. (*Chairman.*) I gather you were rather surprised at the results?—Yes. I was very much surprised because I had not expected them.

3122. (*Professor Ramsay.*) Did solid matter go into that under-channel?—Everything with the exception of grease, which I will refer to presently.

3123. (*Professor Foster.*) You stopped the grease?—Yes. I refer to that as an important element.

3134. (*Chairman.*) Then you came to the conclusion that the apparatus you had constructed did aid nature very materially in carrying out what you looked upon as a necessary preliminary in the way of liquefaction?—I did come to that conclusion.

3135. Were there any points that required attention in order to obtain these results?—I found it necessary to keep back all grease in a properly constructed grease trap.

3136. In what way did the grease interfere with the process of liquefaction?—It principally interfered with it by mechanically arresting the whole process as the organisms seemed to be quite incapable of carrying on their work in a greasy medium.

3127. And did you find any difficulty in keeping back the grease?—None whatever—a good grease trap was all that was necessary.

3128. Does your further experience lead you to believe that this difficulty of the grease would be a serious one in the case of large installations?—The difficulty seems not to occur in the case of large installations, because the grease appears to be sufficiently broken up in the passage of sewage through long lengths of sewers. It is emulsified, and does not appear in the form of a mechanical clogging of the process. That is my experience.

3129. What about the case of trade refuse, which may contain a large quantity of grease?—In those cases some special provision should be made.

3130. By providing the means for the removal of the grease?—I think that in all communities the grease should be arrested as near as possible at the point of its discharge—in the case of houses by grease traps, and in the case of manufactories by some similar appliance. I mean factories producing grease.

3131. In point of fact, your opinion is that grease represents difficulties of a special character?—That is my view, yes. I look upon grease, both from residential and manufacturing communities as a matter that should be dealt with separately.

3132. And that special arrangements shou'd be made for it?—Yes, I think so. I think, if I may say so, that in all cases it would more than pay for the cost of collection, and it is certainly a standing nuisance in the areas of the better class of houses in all our towns.

3133. Do you refer only to grease that has been intercepted before being mixed up with the sewage system in any way?—Certainly, yes.

3134. And do I understand that as far as your bacteriological processes are concerned, you have found no difficulty when the grease has passed with the sewage along considerable distances?—No, in these cases it is sufficiently emulsified, and the buteric fermentation seems quite capable of dealing with it. It does not present itself in any form that is hurtful to the process.

3135. How does the buteric fermentation deal with it?—Well, first of all you get a conversion into fatty acids, and later you get carbonic acid and water. I mean to say it disappears altogether as grease.

3136. In dealing with the sewage in your apparatus what amount of sludge did you find?—In the case of a single house the inorganic detritus was, of course, very small; my experience throughout, and without any exception, is that the organic sludge is quite a negligeable quantity.

3137. (*Professor Foster.*) Compared with the inorganic?—The organic sludge is quite a negligeable quantity. That is an invariable experience.

3138. (*Chairman.*) How have you dealt with it at your house as Ashtead, for instance?—The whole sludge of the last seven years has been absorbed upon a piece of land not more than about 9ft. by 9ft., or nine superficial yards, and there is no distinction in appearance between this soil and the soil surrounding it. There is no evidence of sludge in any way.

3139. Now, may I ask where that land is situated?—Immediately opposite the apparatus; it is contiguous to it.

3140. It is contiguous to the apparatus?—It is the actual plot of land upon which the apparatus is placed.

3141. Is there any provision in your apparatus to prevent the sludge getting into your cultivating tank?—No, none whatever; it simply does not exist in the ordinary meaning of the term sludge.

3142. I do not quite understand. Does the sludge stop on this bit of land that you speak of?—It disappears; it is absorbed in the land. It takes the form of humus, and any sand, any inorganic matter, simply becomes identical with the soil in the form of sand or silica.

3143. (*Professor Foster.*) Where do you take out your sludge?—From the valve or penstock shown on the accompanying drawing.

3144. That first bed?—That first bed, yes. At Ashtead it is done by means of a chain pump at intervals of two or three months, whatever it may be. There is a gradual accumulation—a very gradual accumulation—of the organic detritus of the system which takes the form of humus.

3145. Do I understand the sludge is there?—It falls (*showing on diagram*) into the sump *A* when the penstock *B* is opened.

3146. It falls back there before the material goes into your channel here?—The whole of the sewage enters the channel beneath the grating shown on the accompanying drawing.

3147. But you say you take your sludge out here. How does the sludge get in there before you take it out?—It is formed from the sewage gradually.

3148. (*Chairman.*) The whole sewage goes through a pipe?—That is, the whole sewage passes down the pipe and into the channel beneath the grating pipe, and what was sewage yields a certain amount of insoluble humus or sludge, and what is not sludge may be spoken of as sewage.

(*Mr. Killick.*) Mark where the sewage enters, because I must say I am not quite clear.

(*Professor Foster.*) Add an exposé.

3149. (*Mr. Killick.*) Begin at the beginning and follow the sewage?—That practically is the Ashtead arrangement. (*Pointing to the diagram.*) This is a penstock (*indicating*), and that is a sump. The penstock prevents a discharge.

3150. Is this a surface plan; are we looking down on it?—No, this is a longitudinal section. Everything comes down unstrained in any way except the grease, which is kept back in the grease trap. It then descends here, and this is the grating, of which that is a cross section. (*Pointing to the diagram on the wall.*) Well, that being the grating, you cannot make any distinction between sludge and sewage, which are simply mixed up here, the sewage coming in here, and rising in this direction.

3151. The sewage rises then?—The sewage rises there, through these flints and overflows?—At the level of the overflows it can be taken off either at the side or at the end.

3152. And stopped here?—The process goes on, the sewage rising through the grating and flints and escaping, the whole capacity of the tank being about one day's discharge of sewage.

3153. Do you keep the penstock down for a day?—Oh no, for months. The paper and fœces and all the discharge of the household passes in here and is liquefied; it disappears, it goes off in solution, into a liquid.

3154. (*Chairman.*) This is a closed pipe?—Yes, that.

3155. The paper does not choke the grating?—No, it goes on for months and months. If there is any sign of choking all that is done is to open the valve or penstock *B* and pump the contents of the tank on to a piece of

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ground. The whole sludge of seven years has gone on a piece of ground less than the size of this table.

3156. It is not the sludge that is pumped out there, it is the liquid that is pumped out there?—No.

3157. What settles in the dip; this is the sludge?—That is the sludge, yes; it is discharged at intervals of two months or so over a piece of ground. That is totally different from the effluent.

3158. That is what you call the sludge?—Yes.

3159. It is the material passing through there which has not been digested?—Quite so, and never will be digested. It is the detritus of the process, in fact. It has so much of the character of humus that in throwing out flints that have been in use for a couple of years, and exposing them for a time, you could not tell there had been any filth among the stones, it is like a very fine greasy garden mould; like the soil of a worm cast.

3160. What you have at the bottom here, the organic detritus, is a thick, black looking stuff?—That is so. Of course, it comes away with a gush along with the undigested sewage; the entire contents of the tank being pumped on to a piece of land every two months or so as described. The discharge is so infrequent that between each there is time for the soil to completely assimilate the organic matter.

3161. (*Mr. Killick.*) There must be some inorganic detritus here, too?—Oh, no doubt.

3162. (*Professor Foster.*) It is only your own house?—Yes.

3163. Is that offensive?—The discharge from the penstock is offensive, but this soon passes off and it can of course have earth thrown over it.

3164. (*Chairman.*) The detritus at the bottom here is excluded from all air, I suppose?—Yes, there is no attempt at aeration of any sort; there was in my earlier experiments, but not now.

3165. Having got so far, what are the further steps you take towards the solution of the problem?—In the autumn of 1892 I put myself in communication with Dr. Sims Woodhead, and explained to him the nature of the work I had been doing. He encouraged me to go on with it, and I found the greatest possible assistance from his text book upon "Bacteria," which was published about this time. On looking about for explanations of the causes which were at work, I found the monumental work of Pasteur upon fermentation ready to my hand, and I also found that Dr. Sims Woodhead had brought together and focussed the available knowledge of the time so as to make it intelligible to a layman like myself. I then made quite sure that however insignificant my own share might be in the solution of the problem, that I was fairly on the right road towards its complete solution. I then put up a laboratory close to the "cultivation tank" at Ashtead, and provided it with the necessary bacteriological and chemical apparatus for carrying on a sustained investigation. Through the kind assistance of Dr. Sims Woodhead I was able to secure the services of Dr. Houston, and together we set to work to find out what was going on.

3166. I want to make quite certain what is it that you call the cultivation tank?—Well, it was called a cultivation tank because those surfaces provided the means for the permanent residence, as it were, of large numbers of liquefying organisms.

3167. This is the cultivation tank, the whole of this? (*Pointing to the diagram marked section C D*).—Yes.

3168. (*Professor Foster.*) Did the results of this investigation appear anywhere?—In a report by Dr. Houston in 1893.

3169. Where does that appear; was it published I mean?—It was published.

3170. Where?—It was published by Waterlow Bros. and Layton, and I have copies for the members of the Commission. Of course, this report dealt with an early stage of the subject.

3171. (*Chairman.*) What date was that?—That was in 1893, my lord.

3172. And that is comparatively early in the literature?—I believe it is the first literature that exists dealing with the question as a whole.

3173. How do you mean dealing with the question as a whole?—Without previous deposition or the use of chemicals, and with the preliminary hydrolysis by micro-organisms of the grosser organic matters which is not referred to in the Massachusetts reports.

3174. I believe that at a very early period in your experiments you made up your minds that the process should be divided into two sections, in the first of which the organic matter should be liquefied. What further steps did you take to improve the effluent?—The object I aimed at was to get from the first tanks as good an effluent as possible, and in order to improve its appearance I duplicated them, and used them alternately.

3175. And what was the result of that?—By aërating and resting the tanks I was able to get a more clear and less offensive effluent, but there was practically no nitrification, and it soon became evident that the furthest step that could be made from a chemical point of view was the conversion of the nitrogenous organic compounds contained in the sewage into nitrogen as free ammonia by the passage through the cultivation tanks. That is to say, that any attempt at getting nitrification from an arrangement of that sort proved futile.

3176. Did you look on the duplication or grouping of the tanks in which the bacteriological action took place as of importance?—At that time, and still, it does embody a very important principle, because if you are going to get nitrification by any arrangement of that sort, resting by means of duplicating or grouping is absolutely essential to obtain any results worth speaking of. Duplication was taken up by Mr. Dibdin, and afterwards by Mr. Cameron. In 1893 I recognised it as necessary, but I also found out that at any rate in dealing with crude sewage the first operation should be of an anaërobic character, and that duplicating and resting would only give favourable results upon the effluent obtained from the preliminary anaërobic change, and also that the nitrification would be nearly proportional, within certain limits, to the amount of aeration obtained from duplicating and resting.

3177. Did you try to obtain nitrification by passing the effluent through open channels containing coke?—Yes. The idea was to provide some means of aeration, and the one that occurred to me was to pass that effluent through long channels, half pipes exposed to the air, and containing coke. One of these, the first I made, was only 30 feet long. Another one was 80 feet long, and estimations were made of the difference between the effluents from the cultivation tank and the effluent that came away from the end of those nitrifying channels, as I called them at the time. But the effect of these was not satisfactory; the nitrification bore a very small relation to the total nitrogen compounds of the effluent in solution.

3178. Now at your own house you have more than one of those cultivating tanks?—Yes, that is so.

3179. And have you put up that system anywhere but at your own house?—Yes. The effluent obtained from that represented at the time rather a remarkable result, because there was the practical disappearance of sludge, and there was also an effluent obtained that was very much more easily dealt with upon land for instance than crude sewage, and I put up various installations, one or two in Sussex, three in Surrey, and so on; some half-a-dozen installations altogether. That was about the year 1893, and the experience obtained from those was invariable as regards the liquefaction of the organic matter, and the practical disappearance of sludge. There was no exception at all.

3180. You put up an installation for the town of Towcester, did you not?—Yes; I put up an installation for the town of Towcester in 1893, taking the discharge from what I was informed was 1,000 inhabitants, but I found out afterwards that there were only eighty water-closets connected to it.

3181. Did this installation consist of duplicate sets of cultivation tanks and nitrifying channels?—Yes.

3182. Does your nitrifying channel come in?—It is not shown there at all (*indicating diagrams*). The nitrifying channel in the case of Towcester consisted of a wide shallow channel immediately following after the cultivation tank. At Ashtead it was simply a half-channel pipe filled with coke, running for a considerable distance.

3183. And the effluent from the tank went along this nitrifying channel?—Along this nitrifying channel.

3184. And what results were obtained at Towcester?—So far as the pollution of the river by the discharge of the effluent was concerned there could be no objection made, because there were no signs of pollution either from

smell or appearance; in fact it was noticed that the ditch, which contained a considerable body of backwater from the river, was clearer below the point of discharge than above it. Dr. Sims Woodhead kindly went down, and made out an elaborate report, which I believe represented the high water mark of the available knowledge at the time.

3185. What is your present opinion with regard to this Towcester installation?—Even judging it from the standpoint of the present time I think it was a fairly satisfactory solution of the problem for a community like Towcester, that is to say, a small community living on the banks of a stream, containing a large body of water not used for drinking purposes, and I understand they have been in great trouble ever since with a small sewage farm.

3186. In what respect do you consider it was satisfactory?—I think the analysis of the brook showed that there was very little to complain of in the way of pollution.

3187. Was it to the analyses of this effluent and the brook water to which you referred in the paper you read before the recent Sanitary Congress at Birmingham?—Yes; and my views with regard to these analyses are given in that paper. If the members of the Commission would kindly refer to the copies of the Birmingham paper they will find the analyses. You will find it on page 5. Perhaps, my Lord, you would allow me, as the most satisfactory evidence that I can give upon this point, to make use of the paper itself, if I may.

3188. Certainly?—Then if the members of the Commission would kindly refer to the beginning of the paragraph beginning "The invariable results."

3189. (*Professor Foster.*) Which page?—On page 4. I think that in answer to one or two questions I have just said that the liquefaction was an invariable experience. I then deal with this very important analysis, which was really a turning point in my views of the process: "The invariable results obtained from several installations of this apparatus proved that practically complete liquefaction of the organic matter could be obtained without trouble of any kind, and that the amount of organic sludge was a negligable quantity. Where there was inorganic detritus it had of course to be provided for by deposition in the ordinary way in a sump or catchpit. It remained to be found out whether or not the breaking up of the organic matter which occurred in the "cultivation" tank was carried sufficiently far to ensure its complete mineralisation under natural conditions." I might word that slightly differently, and say it remained to be found out whether or not the breaking up of the organic matter which occurred in the cultivation tank was carried sufficiently far to enable one to make sure that under favourable natural conditions complete mineralisation would occur. Perhaps it might be a little better expressed in that way.

3190. What do you mean by "complete mineralisation"?—Complete nitrification of residual nitrogenous organic matter. "By some convenient and inexpensive apparatus, and this part of the problem I found to be the most difficult." In other words, the process of liquefaction throughout seemed to come almost by itself; there seemed to be no exception to the comparative ease with which that occurred. Before I go on, if the members of the Commission would kindly refer to the bottom of page 2, they will find a passage which bears very immediately upon this subject: "Sir Edward Frankland in a summary of the work done in the laboratory of the Royal Commission on Rivers Pollution, says: 'All classes of processes are to a great extent successful in removing polluting organic matter in suspension. . . . but the getting rid of suspended matters is a simple problem compared with the removal of organic matters in solution.' This was written years before the employment of micro-organisms had taken a tangible form. It was a strong argument for the removal of as much suspended matter as possible so that the organic matters in solution might be reduced in quantity and more easily disposed of." That is to say, dividing the problem into two parts, one of which was comparatively easy, and one the most difficult, my experience has been exactly the same as the experience of the earlier workers, viz., that getting the organic matter into solution was comparatively easy, but the argument that was drawn from the fact of its being very difficult to get to matters that were in solution, broken down, led to the belief that they should be reduced so much in quantity as possible by deposition in the form of sludge. "This opinion becoming widely embraced by those responsible for the carrying out of sewage works led to the general adoption of precipitation of the suspended matters by chemicals as a cardinal preliminary to all further treatment. Whatever views may be held by Sir Edward Frankland in the light of recent developments there is little doubt that he would have looked upon the bacterial treatment of sewage, at the time of the Rivers Pollution Commission, with anything but favour if he had understood that the first step in the process was to throw the whole of the organic matters into solution. This would appear on the face of it to be opposed to all the prevailing beliefs because it seemed to add to the difficulty of dealing with what was generally admitted to be the most difficult part of the process."

"We now know that the question altogether hinges not upon the amount of organic matter in solution, but upon its instability and susceptibility to further and rapid changes in the direction of complete mineralisation, and we also know that this condition of instability can be much more easily produced by biolysis than by any artificial chemical means. As to the relative difficulty between the first and second stages of the process indicated by Dr. Frankland and very generally accepted, it is evident that if the process of throwing the matters into solution by a bacterial fermentation produced the necessary amount of instability required for a further natural process of mineralisation, the problem would be solved if this process could be completed. There would be no sludge, and there would be a theoretically perfect fertilising medium with all the original organic matter decomposed into the form most readily assimilated by plants." Of course, it was very important to find out as to whether as a matter of fact this preliminary change was sufficient or not, and if you will kindly refer to the analysis upon page 5 you will find what occurred. It will be noticed that the ratio of dilution can be estimated from the amount of chlorine contained first in the effluent, and next in the brook water taken five yards from the effluent outlet, and also in the brook water taken at about 30 yards further down. Taking the chlorine contained as an estimation of the strength of the sewage, it will be noticed that while the dilution was about as 3 to 1, the fall in the quantity of albuminoid ammonia was from ·25 to ·035, or about as 7 to 1, and the free ammonia was about 20 to 1. That is to say, under a condition of great bacterial activity no doubt existing in the water of this particular ditch, and also a fair amount of free oxygen, there was a sudden fall in the amount of unoxidised organic nitrogen in the case of albuminoid from ·25 to ·035 and free ammonia from 20 to 1, while that part of this change which can be referred to the dilution itself was only 3 to 1. "This proved beyond doubt that the organic matter contained in the effluent from the 'cultivation' tank was capable of being rapidly oxidised in the stream, and from this I argued that if channels could be provided with the same amount of dilution, they would be all that was necessary to give similar results." That is to say, that instead of taking the natural back water in the ditch, which might be spoken of as water that should not be polluted, you took an artificial trench as part of your apparatus, you would of course get the same results. "The chemists, however, insisted upon judging the process from the analysis of the effluent as it escaped from the 'cultivation' tanks. The argument about the instability of the organic matter was never entertained at all, and although in the case above referred to, there could be no reasonable objection made to the water that was passed into the river, they said that the process must be judged from the results obtained from the apparatus itself." That is to say, I was judged from an effluent containing a large quantity of organic matter in solution, and the argument that this was in a great state of instability as proved by this analysis was not listened to at all.

3191. (*Chairman.*) May I just interrupt you for one moment. Does the rain water that falls in your own house enter into your sewer?—No, not at all.

3192. Supposing you put three times as much rain water with your sewage, according to your theory would the same thing happen that happened in the ditch at Towcester?—Not at all, my Lord, not at all, because the first thing that would happen would be this: that the oxygen available in the rain water would be all consumed, by the anaërobic changes going on in the tank. It would be thrown away; it would not be available, certainly not; it would be used up by the organisms. The fact of adding a large quantity of rain water would be that no doubt you would raise the level of the aërobic zone a little higher in the tank, but the oxygen, unless it was a very large quantity, would all be gone before the sewage escaped from the tank.

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3193. (*Mr. Killick.*) The dilution must take place after the effluent has been hydrolysed?—Yes.

3194. In that cultivating tank?—Quite so. "This impressed me more than ever with the necessity for providing more highly oxidising conditions. Accepting the analysis of the diluted effluent as a proof that the first stage of anaërobic fermentation was sufficient to produce the required amount of instability in the organic content of the effluent, it was evident that in sewage containing a certain amount of free oxygen the first changes that occurred would be aërobic in character, and even when all available oxygen was absent, it only showed that it had been used up and that some hydrolytic change had occurred as a consequence." Presuming that there is any available oxygen in the sewage at all, the first thing that will happen under any process that is bacteriological in character will be that there must be very active changes going on, produced by the organisms that use up the oxygen of the water employed for flushing closets, etc. That is to say, that although you may take a sample of sewage and find that there is no available oxygen in it, still the very disappearance of that oxygen represents very active changes that have been going on amongst actively liquefying organisms that have used it up, and therefore looking at the process as a whole I think we are quite justified in looking upon it as aërobic to begin with, because you get active liquefaction taking place in the sewers, the available oxygen being used up preliminary to any anaërobic change which may be advisable afterwards. "The process as a whole must then consist of several stages, in the first of which the available oxygen will be used up by aërobic organisms, and the second should depend upon the action of anaërobic organisms with liquefaction of the organic matter, and a conversion of its nitrogenous constituents into nitrogen as free ammonia, with other changes due to the fermentative conditions. The case could therefore be stated in another way, and the necessary sequence would be, first, that favourable conditions should be provided by well-ventilated and self-cleansing sewers for the work of a mixed group of aërobic organisms." Now, that has a bearing upon the whole subject, because, if you have partly anaerobic changes going on in badly constructed sewers, you may have more or less antagonistic forms coming into your control—the point from which you propose to control the whole process by a regular anaërobic fermentation; therefore, it is as well to have proper sewers and a large flora of organisms coming over without anaërobic fermentation, which might be more or less competitive with the fermentation which is regulated and controlled. Again quoting from the paper: "That the conditions should then be reversed, becoming unfavourable to the aërobic and favourable to the anaërobic organisms, and that the conditions should again be reversed, being unfavourable to the anaerobic organisms, and highly favourable to differentiated colonies of nitrifying organisms which are best suited to carry on and complete the final mineralisation of the organic matter by converting the free ammonia into nitrogen as nitric acid." Your hand is forced by nature in this matter. You have got a mob of liquefying aërobic organisms available, and they, as a matter of fact, use up the oxygen—the available oxygen. In doing that you have fermentation going on. If you want, then, to carry on a further breaking down of the organic matter in an anaërobic process, the aërobic changes will be arrested—the conditions should become distinctly unfavourable to the aërobic organisms—the ordinary organisms of aërobic putrefaction. Then having broken down the organic matter to the point which is known to be most available for nitrification, you must reverse the process, and have highly aërobic conditions. This is familiar to every member of the Commission. Now, presuming that the "cultivation" tank, as above described, was a satisfactory method of carrying out the first two stages, I give this typical analysis made by Dr. Rideal.

3195. (*Professor Foster*). That is the same as we have on the paper here, is it?—Oh, yes, further on, page 7. Yes, I can deal with it here; you have it on page 7. Now, presuming for a moment that the hydrolysis, the breaking up process through the anaërobic fermentation, has been carried to a proper point, you have here a typical analysis; it shows results which are practically constant at Ashtead; the arrangement at Ashtead, having been at work so long, has become exceedingly constant in the results it gives. It was irregular for a long time, but now there seems practically no change from month to month. Formerly it was interrupted by discharges of bath water, but apparently the organisms have established themselves in colonies or in zones upon the flints in such a way that the results are exceedingly constant, independent of changes of temperature, and so on.

3196. Excuse me; interrupted by bath water?—Yes; any sudden increments of water upset it in the early days of its working.

3197. Any great dilution of the sewage?—Any great and sudden dilution of the sewage. Any disturbing element seemed to have a great effect.

3198. Have you reason to think that there was a certain percentage of matter in the sewage which is an optimum for the action of the cultivation tank?—I do not quite follow.

3199. I mean that sewage of a certain amount of dilution will be worked upon more rapidly than a still more dilute sewage or a more concentrated sewage?—I am referring to that later on in my evidence. May I take a note of that, in case it is omitted by any chance?

3200. I will note it?—Thank you. Here there is a chlorine content in the first column of 9·0, a free ammonia of 12·5, an albuminoid ammonia of 1·50, oxygen unconsumed, and so on. Of course, the chlorine stands by itself, but taking the other elements, there is no reason for forming a judgment that because this has given certain results there is any necessary finality in those figures—that is to say, that you may have an anaërobic change carried further or an anaërobic change carried not so far, that may possibly give better results, and it is upon this question of the best point at which to arrest or continue the anaërobic fermentation that I am now working. But, accepting that the breaking up of the organic matter is fairly well carried out in the cultivation tank, we then get from a series of protected organisms, colonies of organisms, the results which are shown in the succeeding analyses. The change in the chlorine is not always very easily accounted for, even when the samples are taken as simultaneously as possible.

3201. Are these the trays on the plan?—Yes; these are the trays practically as arranged at Ashtead. The effluent is tilted over these trays.

3202. What is the depth of the coke on the tray?—Seven inches.

3203. (*Colonel Harding.*) What is the nature of the tray which carries the coke?—It is a box perforated at the bottom.

3204. Wooden?—What I have insisted on in the paper read at Birmingham is that you must have protected colonies.

3205. (*Chairman.*) Was it the analysis of this effluent that you referred to in the paper which you read before the Sanitary Congress at Birmingham?—It was, and I have just explained the views that I had with regard to that.

3206. You thought the instability of great importance?—I did. I thought it the key of the whole problem.

3207. And have you found the chemists agree with you in that view?—Well, they are coming round; they will have to come round, I think.

3208. Have you done some work for the town of Aylesbury?—Yes. The Corporation were so satisfied by the reports of a deputation that visited Towcester that they spent about £500 in converting one of their large depositing tanks into what I have called a "cultivation tank."

3209. And were the results obtained satisfactory?—They were satisfactory only in the same sense as those at Towcester. The sewage was hydrolised; there was practically no suspended matter and practically no sludge.

3210. How was the process judged?—It was judged in the same way as before, from the effluent as it came from the apparatus, and condemned.

3211. Did you then think it necessary to find means by which the effluent could be improved?—Yes, and I made many efforts to do so. There was still a belief that the two processes of hydrolysis and aërobic nitrification could be carried out, if not simultaneously, at any rate in the same tank, and at Aylesbury air was forced into the lower part of the liquid contents of the "cultivation tank" by a steam jet. It was a very interesting experiment in some ways, but it only appeared to jumble up the whole process, and it did not add to nitrification in any way. It may interest some members of the Commission to know that the heat from the steam gave rise apparently to the cultivation of a large number of high temperature organisms that had been referred to by

Professor McFadyen about that time, a group that he had discovered; they were gas-forming organisms, and a very offensive smell was the result. By raising the temperature of the "cultivation" tank, whether there is a facultative change takes place in the work of the organism, or whether high temperature organisms come into activity, the experience at Aylesbury showed an extraordinary evolution of offensive gases. These experiments, although carried out upon a large scale, gave no satisfactory results, but one remarkable feature of the effluent at Aylesbury, which had a very strong sewage, was that it was capable of clearing up by itself by simply being placed in a large earthenware dish. The effluent from a very strong sewage, with a high chlorine content, and large quantities of ammonia, would clear up of itself and become quite clear. At the end of the eleventh day, I think it was, the effluent began to clear up, and at the end of twenty-one days it had become quite clear.

3212. At the time you speak of was your process being discussed by Local Authorities and others?—Yes, and two authorities applied to the Local Government Board for power to borrow money to apply it—namely, Rushden in Northamptonshire, and Staines in Middlesex, but in both these instances sanction was refused, in the one case on the report of Colonel Ducat, and in the other by General Carey. In the case of Colonel Ducat his view was that he was not sure of the trade refuse not being fatal to the success of the system, and General Carey's view was that the system had not been sufficiently tried to justify the lending of public money for its adoption at Staines.

3213. Do you know of any other experiments being made?—Yes. Mr. Dibdin had been actively engaged for the London County Council. He saw the Ashtead installation during 1892, but he never seemed to realise the importance of insuring a preliminary hydrolysis of the organic matter. I never could understand how that escaped Mr. Dibdin's notice as an important element. He never seemed to realise its importance. At Barking he dealt only with sewage, which had been treated chemically, and for some time his experiments were carried out very much on the lines of the Massachusetts reports. He then developed the plan of allowing the filters to remain waterlogged and aerated alternately, and published his report of the results obained. That is his well-known report to the London County Council.

3214. Did you think those results satisfactory?—I thought not; I thought they did not embody the proper sequence that should occur.

3215. Why not?—Because I looked upon the system as not altogether anaërobic or aërobic. I have always thought that water-logging the filtering material might give rise to an anaërobic fermentation at any moment. That is to say if you allow it to remain too long it will certainly become anaërobic at the very time that you wish it to be very greatly aërobic. On the other hand, if you get conditions of extra strong sewage coming in or any neglect or failure in any way the process that is intended to be highly aërobic may at any moment become anaërobic in its character, and upset, of course, any aërobic change.

3216. And you thought that this would interfere with the proper action of the filters?—With the nitrifying action of the filters.

3217. But your cultivation tank is always water-logged?—Yes, but this is with the object of continually keeping up an anaërobic fermentation.

3218. And you did not advocate the mixing up of the aërobic and the anaërobic processes in any way?—In the light of my more recent experience I certainly think not.

3219. Do you know of any other systems?—There is Mr. Cameron's system at Exeter. I have seen the installation at Belle-Isle, and read several reports upon its working. Mr. Cameron has realised the importance of separating the anaërobic from the aërobic fermentation, but has adopted the filters reported upon by Mr. Dibdin pure and simple, with the addition of certain mechanical appliances.

320. You spoke just now of your more recent experiences; what did you refer to?—After years of thinking over the process in its many aspects the problem on its bacteriological side at last presented itself to me in this way that there was, to start with, a mixed mob of organisms in the sewage, which should be utilised as far as possible, but that the final changes in mineralisation must be carried out by distinctly nitrifying organisms, and that these must be in some way protected.

3221. What do you mean by protected?—That they should be free to work without being interfered with by conditions favourable to other organisms or by these organisms themselves.

3222. Does your own system, or any system that you know of, supply these conditions?—The arrangement that I have fallen upon apparently does supply these conditions, and now if the members of the Commission would kindly turn to that analysis on page 7:—

TABLE showing successive stages of Mineralization by Nitrifying Organisms.
Ashtead Experiments, February, 1898.

	Description of Samples.	A Chlorine.	B Free NH_3.	C = N.	D Albuminoid NH_3.	E = N.	F Oxygen consumed.	G O consumed minus O required by Nitrous Nitrogen.	H Nitrous Nitrogen.	I = Oxygen required.	J Nitric Nitrogen.	K = Equal Useful Oxygen. N_2O_3 to N_2O_5.	L Total Oxidised Nitrogen.	M Available Oxygen useful O. Nitrate = O. consumed.	N Total Unoxidised Nitrogen (Kjeldahl).	O Total Organic Nitrogen.	P Total Inorganic Nitrogen.	Q Total Nitrogen of all kinds.
	Effluent from Cultivation Tank, taken 3 and 5 p.m.	9·0	12·5	10·30	1·50	1·23	9·843	9·843	Nil	—	0·12	0·274	0·12	– 9·57	12·35	2·05	10·42	12·47
Colonies of Aërobic Nitrifying Organisms.	1. Effluent from First Tray	9·0	10·5	8·65	1·25	1·03	6·694	5·56	0·99	1·13	0·096	0·219	1·086	– 6·47	11·5	2·85	9·74	12·59
	2. Effluent from Second Tray	8·5	9·0	7·42	1·00	0·82	5·773	4·74	0·90	1·03	0·48	1·09	1·38	– 4·66	11·10	3·68	8·80	12·48
	3. Effluent from Third Tray	8·5	5·0	4·12	0·60	0·40	4·493	3·60	0·78	0·59	1·87	4·27	2·65	– 0·22	6·60	2·48	6·77	9·25
	4. Effluent from Fourth Tray	8·0	4·0	3·3	0·35	0·29	1·728	0·98	0·66	0·75	2·76	6·30	3·42	+ 4·58	5·15	1·85	6·72	8·57
	5. Effluent from Fifth Tray	7·75	1·5	1·24	0·15	0·12	1·28	0·78	0·48	0·55	4·68	10·70	5·16	+ 9·42	1·75	0·51	6·40	6·91
	6. Effluent from Sixth Tray	8·0	1·75	1·44	0·35	0·29	1·497	0·92	0·51	0·58	4·416	10·10	4·926	+ 8·61	2·25	0·81	6·37	7·18
	7. Effluent from Seventh Tray	7·5	0·35	0·29	0·30	0·25	0·755	0·755	Nil	—	6·6	15·08	6·6	+14·33	0·85	0·56	6·89	7·45
	8. Effluent from Eighth Tray	7·5	0·2	0·165	0·65	0·53	0·397	0·397	Nil	—	7·32	16·73	7·32	+16·34	1·03	0·865	7·48	8·35
	9. Effluent from Ninth Tray	7·5	0·25	0·206	0·60	0·49	0·589	0·589	Slight trace.	—	9·0	20·0	9·0	+20·1	0·60	0·394	9·21	9·60

3223. (*Professor Foster.*) Before we go into an analysis would it not be better to have an explanation of the trays themselves?—Certainly.

3224. (*Colonel Harding.*) Before you get to the trays would you explain what these are (*pointing to the diagram*)?—That will come later on. With regard to Professor Foster's question these are simply trays superimposed one upon the other with air spaces between. There is absolutely nothing more in it. The effluent is distributed over the top of those trays.

3225. (*Professor Foster.*) It passes from one tray to one below?—From one to the other. It does embody this

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principle that here you have the hydrolysed sewage coming over here (*indicating on the diagram*), and you have got certain organisms which have been associated with the anaërobic fermentation in the "cultivation" tank. I will go later on into the question of whether or not this can be carried too far. Well, it comes over here. These you see will represent a food supply. Now, whatever bacteriological change goes on here, it must be in the direction of further breaking down of the organic matter, and it represents a distinct kind of food supply so long as the conditions are uniform. Now that specific food supply will in the course of time give rise to a survival of organisms best suited to deal with it; therefore you can see that for any specific food supply in course of time you will have a specific colony of organisms dealing with it, but the more effectively they deal with that food supply they will the more certainly pass on a different chemical compound to the organisms in the tray immediately beneath, and so on till the lowest tray is reached. It is perfectly certain as you go on attenuating the food supply you must come to a stage in which the organisms of the upper trays cease to exist altogether, and so at last you come down through a series of colonies, each more or less protected, till at last you get a group or survival of nitrifying organisms which are best suited to the final food supply in the bottom tray. You can see the proecss of rapid mineralisation which goes on by referring to the analysis of the filtrate from each successive tray.

3226. Each is a wooden tray with a layer some seven inches deep, of pieces of coke, each of the same depth, each of them having similar pieces of coke; they do not differ, except in position?—Quite so. Now here, in this analysis, you get what actually occurs in each of these differentiated colonies. In the first you get a change representing the difference between 10·5 and 12·5 free ammonia; in the next you get that falling down to 9·0; in the next you get a more rapid change, in which the free ammonia has fallen down to 5·0; the next to 4·0; the next to 1·5, until you get a minimum of free ammonia represented by 0·20. I do not know what evidence has been brought before the Royal Commission; but I fancy that a good deal of that evidence has gone to show, especially in the case of Mr. Adeney, that this nitrifying process is an especially slow one. Now, as a matter of fact, this extraordinary change, the fall from 12·5 to a minimum of 0·20 at the eighth tray takes places in something under eight minutes, so that the process, instead of being a slow one, is an exceedingly rapid one, incomparably more rapid than the anaërobic change which has hitherto been believed to be the most rapid. It occurred to me, of course, that the moment one got an arrangement such as I have described, one would be able to have it plotted out in the form of curves, and here you have the whole process represented diagramatically, the changes being shown diagramatically. These represent the various colonies, one, two, three, four—(*indicating on diagram*)—and these represent the parts per 100,000. The result of this is that you can get an accurate estimate of what actually goes on during the whole process. You see the inorganic nitrogen and the total nitrogen, the lines at which they run out, these being represented by the various figures of the analyses. Here you have the lines of increase as well as the lines of decrease; here you have nitric nitrogen increasing, and here you have the nitrous nitrogen decreasing. Here you have the oxygen consumed decreasing, and here, at the fifth tray, you see an extraordinary setting back of the line forming this triangle, which shows that there is some critical biological condition occurring here, which is actually shown by these various lines. But multiplying the line of nitrous nitrogen by ten you get this triangle. At the same time there has been a setting back of the oxygen consumed, which practically corresponds with this line, so that there is accurate information to be obtained at every part of the process until you get towards the condition in which the organisms will be denitrifying organisms instead of nitrifying organisms, and the point of highest purification in terms of oxidisation has been passed.

3227. The successive trays run this way (*showing on chart*)?—The successive trays run this way, and the parts per 100,000 are the vertical. That is to say, this represents an increase of nitrogen; this represents a falling off of oxygen consumed.

3228. The curve of nitric nitrogen is seen here?—No. nitric nitrogen comes straight on until it comes up to nine parts per 100,000. It is set back there.

3229. And your curve of nitrous nitrogen comes (*showing*)?—Yes, and there it sets back the other way. The final nitric nitrogen conversion is nine parts per 100,000, representing an oxidation of 96 per cent. in a sewage with a content of nine of chlorine. Now, with regard to the results to be obtained from filters that are alternately filled and emptied or water-logged and emptied, there is nothing at all approaching to these results. I took out some averages here from ·125 to ·200 parts of nitrogen as nitrate per 100,000 in the case of Exeter, and from about ·07 to 1·6 per 100,000 in the Barking experiments, or a mean of about one part per 100,000. So the mean of Ashtead is eight times more, obtained by this means of differentiated colonies, than is obtained from the water-logged filters, which I think was only to have been expected. Then to prove that there was a biological sequence by simply taking one of the boxes out, say, No. 8 or No. 7, whatever it was, and putting it in the place of No. 2 or 3, and leaving it there, the whole process was at once upset, and a very bad effluent was the consequence.

3230. How often did you try that?—I only tried it once, and the process broke down altogether.

3231. How long have they been going on, those trays—up to the time when you made this shifting, how long had they been at work?—From the 25th October, I should think, to the beginning of February.

3232. (*Chairman.*) How long have your works at Ashtead been up altogether?—The cultivation tank has been at work now for seven years.

3233. Seven years?—Seven years, yes. The sequence only occurred to me when I was abroad in the autumn of the year before last, and when I came back I put up this apparatus, and I have never changed it in any way. The cultivation tank has never been altered in any way, and there is no alteration apparently required in the arrangement of the trays.

3234. But the trays have only been up——?—Since the 25th October, twelve months. I allowed them to run three months before doing anything, because I wanted to see whether there was any clogging, or anything requiring alteration, and Dr. Rideal having made his series of analyses, we plotted out those lines.

3235. Did you have your effluent from your cultivation tank analysed before the trays were put up?—Yes, quite so, before it was passed into the trays at all. Yes, it is here. It is the first line here, 9·0 chlorine, 12·5 free ammonia, 1·50 of albuminoid ammonia, oxygen consumed 9·843, and so on. That is the effluent as it comes over, the hydrolised effluent containing, you see, no available oxygen at all.

3236. This analysis is made quite recently—in February, 1898?—That was made in February of 1898, yes.

3237. Then had you had the effluent from the cultivation tank analysed in previous years?—Dr. Houston made a large number of analyses.

3238. And you have not found them vary very much?—No. It has always been very much the same. I am not prepared to say what the difference is. You will see it by comparing Dr. Houston's report. As time has gone on the results obtained from the "cultivation" tank have become more and more even and constant.

3239. Then you consider that the addition of the trays has been a very great feature in your treatment of sewage?—I think it has made all the difference, absolutely all the difference. Dr. Sims Woodhead here in a paper read before the Sanitary Congress, gives a series of analyses that he took independently altogether, in which he gives the average of nitric nitrogen found as 6·82 per hundred thousand, free ammonia. When the trays had been out of use for about a week and then set to work the first results were as low as 5·349 of nitric nitrogen, and this lowered the average; but taking it all over, the mean of the Ashtead nitrification is represented by about 8 to 9 parts of nitric nitrogen per 100,000.

3240. Now, at Towcester and at Ailesbury you did not have these trays at all?—No. What I did discover at Towcester was the extraordinary instability of the effluent as judged by the disappearance of polluting matters in that particular case.

3241. Well, now, I believe you have put up an installation tank at Caterham, which takes the entire discharge from the barracks. Is that similar in principle to the arrangement that you have shown on the diagram?—Quite so. At Caterham, I was anxious that the Caterham installation, which is dealing with the whole of the sewage from the barracks, should embrace all the require-

ments of a complete experimental apparatus; and I need hardly say, my lord, that the Royal Commission is heartily welcome to any use that they may wish to make from an experimental point of view of that installation.

3242. Then, that has got the trays I suppose?—That has the trays; but it has also got what Colonel Harding asked about, these inverted pots. Now, I was very anxious at Caterham to be able to clear up this question of the proper stage to which the anaërobic fermentation should be carried, because there ought to be some standard with regard to these anaërobic changes. In the case of the trays in which nitrification takes place, one ought, of course, to be able to take a certain standard of sewage, hydrolysed sewage, with a certain standard of chlorine, and a certain standard of free ammonia, and be able positively to say that so many trays under such and such conditions are capable of producing a certain result. There ought to be no difficulty in that at all; that is to say that for a certain standard of nitrification one should be able to say four trays are necessary, for a higher standard five trays, and so on. There ought to be no difficulty whatever in the light of this knowledge in determining the relation between the depth and the number of those filters, for any standard of sewage. There has been complete ignorance, so far as I know, of the actual facts with regard to the anaërobic change, and no data to go on as to whether it was possible or not to carry it too far. I thought the only way to overcome that was to have an estimation by error. I determined, if possible, to see if I could carry this anaërobic change too far, and here you will see I have a large chamber at Caterham; it is twenty feet wide by ten feet by nine feet deep, and this was filled with inverted, glazed, earthenware pots. There were 400 of them, representing a surface of about 300 square feet. Now the hydrolysed sewage was brought in beneath these pots, and had to percolate through the occluded gases, which were the product of the anaërobic fermentation. The consequence was that you might have chemical conditions set up which are peculiar to these very highly anaërobic conditions. The formation of compound ammonias which are highly toxic in their character, and fatal if in excess to the working of any organisms in the future process was the result. It was also an important thing to discover if the anaërobic change could be carried too far, with a view of finding out if you could kill off all the aërobic organisms or the organisms which may be capable of doing their work by too high an anaërobic condition, and that I am glad to say I have succeeded in proving. The anaërobic change was carried to a point at which the nitrification was completely suspended. Nitrification having risen to 2 parts per 100,000 went back to zero, and the whole oxidising process practically stopped. Of course that was a very important thing to discover; it was an unknown country altogether, and Dr. Rideal has prepared a very elaborate chemical estimation of the results obtained from this very high anaërobic fermentation. One then had to go back along the cultivation tank by tapping it at different points until you came to a stage at which the anaërobic change was insufficient to give good results. That investigation is not completed; I hope it soon will be; but I am pleased to be able to inform the Commission that I have gone back to a point at which the whole process restarted, and from which nitrification has gone up to eight parts per hundred thousand. I hope, before long, the Commission will be in possession of all the facts about the anaërobic fermentation, as in the case of the nitrifying changes which occur in the trays.

3243. I did not catch the number of people?—There are 1,180 and two horses.

3244. At Caterham?—At Caterham, yes.

3245. And that is the largest place in which your system is in operation?—Yes.

3246. How long is it since it was started there?—It is just started, and has not yet had time to ripen fully.

3247. And you would let us go down and visit it?—It is entirely at the disposal of the Royal Commission.

3248. I am sure we should like to visit it some time?—I think, as far as I know, Caterham affords an opportunity of carrying out the whole of these investigations. I do not know any point that will not give an opportunity of carrying out any investigations, one of the most important conditions being that you are able to get any strength of sewage by accumulating the fœcal discharges in the morning without diluting it in the afternoon, and I have got as much as forty parts per 100.000, twenty of ammonia, and thirteen of chlorine. So that I am dealing with sewages up to almost any strength.

3249. Is there anything more about the Caterham sewage you would like to mention?—In dealing with very strong sewage such as that at Caterham, with a chlorine content of 18 parts per 100,000, there seems almost no limit to the capacity of the anaërobic ferment under favourable conditions to break down the nitrogenous organic matter into nitrogen as ammonia, seeing that I have already obtained as much as 35 parts NH_3 per 100,000 against about 5 parts per 100,000 in the Belle Isle experiments. It is this production of ammonia that I expect will afford a measure of the maximum of anaërobic change in any particular case which gives the best results.

3250. In very strong sewage, such as you speak of, what do you consider ought to be done with the nitrogenous organic matter?—All the nitrogenous organic matter should be broken up into nitrogen as free ammonia before being oxidised to nitrates, but there is a limit to the amount of this ammonia if it is to be treated bacteriologically.

3251. And what happens if the limit of free ammonia is passed?—That I am not prepared to say. All that I argue is that there is some limit in the matter of free ammonia, and that you can get ammonia to such a point, produced bacteriologically, through the agency of anaërobic fermentation, that it may become toxic to the nitrifying organisms, but what point that is I am not prepared to say.

3252. Would you dilute the sewage?—Yes; but if there is to be dilution, that is to say, if you have a very strong sewage which you can deal successfully with in some such apparatus as this cultivation tank, and you find it is too strong to be dealt with on account of the ammonia or bacteriologically toxic compounds coming over from the anaërobic fermentation, the proper point to dilute it is before it is subjected to the nitrifying process. If the diluting water is put into the sewage which is passing through this anaërobic mass, the oxygen contained will be used up, and will not be available for the purposes of nitrification, nor even dilution in the oxidising sense; whereas if you do get too high an ammonia or get a toxic effluent of any kind by diluting before nitrification takes place, you get the available oxygen of the diluting water at what I think is the proper point.

3253. Then you consider that investigations upon these matters are very necessary?—I certainly do, because unless these questions are settled, every statement will have to be qualified in accordance with the strength of the sewage to which it refers, and these must remain more or less empirical until we know in terms of what amount of ammonia and nitrates the purification is taking place.

3254. And will these considerations apply equally to the case of weak sewage?—They will, in this way, because, presuming the Ashtead experiments, or similar experiments, if there are any, give something approaching finality in the results, and if 9·00 parts per 100,000 of nitrogen as ammonia coming over from the anaërobic fermentation gives 9·0 parts per 100,000 of nitrogen as nitrates in the final filtrate, this or some other definite relation should be made the standard of efficiency, and these should be given in terms per cent. I may mention that I have had a very important letter from Dr. Rideal. I asked him for a table of percentages. He and I seem to have been working on much the same lines; he has been very strong on this subject—of course he knows a great deal more about it than I do—I can send it to you.

3255. All these ratios in your opinion will have to work within certain limits in the amount of free ammonia?—Well, I am very much inclined to think that these ammonia limits will not in all probability come into practice unless in exceptionally strong sewages. What I mean is that there will be no ordinary sewage that is so very strong that it will be outside the limits as regards ammonia. I hope to be able to speak positively about this very soon.

3256. In fact, you are in hopes that at Caterham your work will throw a good deal of light on the anaërobic processes?—Yes. I have been given a free hand by the War Office. The sewage there may be run down to a field—a small sewage farm—so that there are none of the difficulties attaching to ordinary public requirements, and every strength of sewage can be artificially obtained for the purpose of experiment.

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3257. And you can take the sewage at different times?—At different hours of the day, and accumulate the fœcal matter so as to have any standard of impurity.

3258. And Dr. Sims Woodhead and Dr. Rideal are both cognisant of what you are doing?—Yes, they are.

3259. (*Mr. Killick.*) In your table, page 7, column F, "Oxygen consumed," that is the actual consumption of oxygen?—Yes; that is at 80 degrees centigrade, for four hours.

3260. Eighty degrees for four hours, that is; is it not at sixty degrees?—Sixty degrees.

3261. Sixty degrees?—I think it is eighty degrees, Dr. Rideal recommends.

3262. The limit of impurity recommended by Sir Henry Roscoe, taking the Mersey and Irwell, is 1, so that you see you get well under that?—·039 is the lowest. In taking these samples, plates were slipped beneath the trays, so that the samples were taken simultaneously, but there is a rise in the albuminoid ammonia there which we cannot account for.

3263. But this is oxygen consumed; there is a rise there?—That, no doubt, would arise from disturbance of the filtering material.

3264. And at the end it is not a very good effluent by your test?—·5.

3265. ·5 is not a good effluent. You get better effluents from all kinds of sewage treatment, land filters, and even tanks?—I do not suppose you get nine parts of nitrates, do you?

3266. No; I am only taking these two tests?—Yes.

3267. Taking the albuminoid ammonia, column D, the limit of impurity there that we allow is ·1?—Yes.

3268. This column is very puzzling in that light. You see, it falls in tray five to ·15?—·15.

3269. It rises then in tray nine to ·60, which, on your basis, is a very bad effluent?—Yes. I have no doubt that that arose from taking the samples. You see, the slightest disturbance would detach organic matter from the filtering material.

3270. The results of these analyses from the last tray judged by those two standards?—If it has got to be an albuminoid test, well, of course, the saving of four trays would be a great point, and you would get what you wanted in the fifth tray instead of the eighth.

3271. By these two tests, albuminoid ammonia and oxygen absorbed, it is not satisfactory? The albuminoid ammonia is very unsatisfactory, and the oxygen absorbed is only just satisfactory. Do you attribute that to the tests being untrustworthy, or to the apparatus not being so satisfactory as it might be?—Well, Dr. Rideal took these analyses; I am really not responsible for them.

3272. At Caterham, I understand, you receive the sewage from 1,100 people?—1,180 persons and two horses.

3273. That is, 25,000 gallons a day?—22,000 gallons is the return that I have had.

3274. 22,000 gallons, and you have how many trays there?—Seven.

3275. Are they one super-imposed upon the other, or are they in sequence?—One super-imposed upon the other.

3276. In dealing with a very large volume of sewage, say, 10,000,000 or 20,000,000 gallons, would it be possible to deal with it by a system of superimposed trays?—Taking the apparatus as arranged at Caterham, of course the units could be multiplied indefinitely, and deal with any number of gallons of sewage.

3277. What area does your plant at Caterham occupy?—The plant at Caterham occupies 1,600 square feet.

3278. Is it suitable in extent to the amount of sewage it has to treat?—It is too large—I cannot tell you how much, but it is.

3279. How much do you think?—I cannot tell you, it is too large.

3280. (*Colonel Harding.*) The interesting experiment which for some time you have carried on at Ashtead is, of course, on a very small scale. I suppose the volume would be 250 or 260 gallons a day?—About 250 gallons.

3281. It would be difficult to draw any inference from so small an experiment which would be of much value?—Dr. Sims Woodhead and Dr. Rideal drew their conclusions from it.

3282. Then your arrangements there may be considered as mainly in two parts; first, the septic anaërobic arrangement, and secondly, aërobic filtration over trays?—That is so. I do not altogether understand the term "septic."

3283. Well, I was using it as an alternative to "anaërobic"?—Yes.

3284. Anaërobic fermentation?—Yes.

3285. To what extent does the sludge in the small experiment at Ashtead accumulate; what proportion of it is liquefied, and what proportion of it accumulates in the chamber which is occasionally emptied, you told us, by the opening of a valve?—In terms of a dry residuum I should think it is almost incalculable, the smallness; it must be quite negligeable; I mean it is negligeable as it is; but if you treat it as a solid dry residuum I cannot tell you how small it is.

3286. But take it as sludge; how many bucketsful per month or year?—Well, you may take it that the contents of the filter-bed might be emptied once in three months at the extreme outside; that is four times a year.

3287. Let us not confuse. You say "filter-bed"; I am speaking at present of the first stage?—The first stage, which is the cultivation tank.

3288. The first stage; it is the contents of this lower chamber which is occasionally emptied?—Yes, or the whole chamber for that matter in a small installation.

3289. Can you give us any idea what relation the part that is removed bears to the total of the solids that are passed into the chamber?—I cannot give you any answer at all; it does not appear; it is not in evidence in any way.

3290. At Caterham, where you are dealing with 22,000 gallons a day, you have the same double arrangement; first, an anaërobic liquefying treatment, and secondly, a nitrifying filtering treatment through trays?—Yes.

3291. What is the size or area of the trays at Caterham?—800 feet less 20 per cent.

3292. What is the size of each tray—how long, how wide?—10 by 10.

3293. Ten by ten?—Yes, 100 feet.

3294. Is the tray there constructed also of wood?—No; it is constructed of perforated cement slabs.

3295. Cement slabs?—Yes.

3296. And how thick are the slabs?—Two inches.

3297. With holes?—With holes; they are two inches apart.

3298. How large are the holes?—Three-quarters of an inch in diameter.

3299. What is the depth of coke carried by each tray?—Eight inches.

3300. Does the size of the coke vary with the various trays, coarser at the top and finer at the bottom?—That is all being subject of experiment. There are eight nests of trays there, so that we can ring the changes upon any filtering material, and at present we have a large number of filtering materials. The best results obtained at present are from small coke giving eight parts per 100,000 of nitrates. Of course, all these anaërobic experiments were stopped, and in going back there has been comparatively little time for anything to be done, but it was through fine coke that the high nitrate was obtained of eight parts.

3301. You said the size of your trays was ten by ten, but you have a series of them lateral as well as vertical, have you not?—They are formed in nests. There is a four-inch wall with headers coming through at intervals, and these are three feet three inches apart, and these slabs are laid upon the headers so as to form a series of trays, and then there are more of these which make up the ten feet, and they are ten feet deep, and there are eight of them which makes up the eight hundred feet.

3302. Then is each nest ten feet by ten feet?—Yes.

3303. And there are eight of these?—There are eight of these.

3304. When was that installation started?—It was started, I may say, in September.

3305. This year?—This year.

3306. And it has been working continuously?—Yes, it has been working, and has been looked upon as an experimental station as well as on a thoroughly practical scale. I am anxious to get the same information with regard to

anaerobic changes from that I was able to get on a smaller scale from Ashtead with regard to nitrification.

3307. Should I be right in considering your arrangement at Caterham as a variation of Mr. Cameron's arrangement at Exeter, which also consists, first, of a septic or anaërobic liquefaction, and then filtration?—I think I have dealt with that in my evidence.

3308. But it is a modification of the same idea?—I think it is totally different; as different as those things can be.

3309. Where is the difference in principle?—Of course, in the sense of their being both biological, the principle is the same, but as regards the embodiment of the principle I do not think you could get any much greater differences than there are between the two.

3310. But in both cases you have first an anaërobic liquefaction, and this is followed by aërobic filtration?—While in the case of the Exeter installation Mr. Cameron has an empty tank, I have a tank full of flints.

3311. I am quite aware that there are differences in details, but the main principle in it is the same, is it not?—Well that embodies a very important difference in principle; it means the difference between a nomadic and a fixed population, which is a difference in principle.

3312. How soon do you expect the installation at Caterham to have reached an effective stage?—I think it has reached that now. I think with eight parts per 100,000 of nitrates in a sewage with a chlorine content of thirteen parts per 100,000, and dealing with an amount of ammonia of twenty parts per 100,000, the results are far in excess of any other that I know of. I mean to say there is no comparison at all.

3313. Are you able to give us the cost of the installation at Caterham?—No, I am not.

3314. Approximately?—No; it has been carried out for experimental reasons, and it is out of all proportion to the cost of an ordinary installation.

3315. Following a question of Mr. Killick's, have you considered the application of your system on a large scale?—Certainly. I think that if the Royal Commission are able to satisfy themselves at Caterham that certain results can be obtained from a range of sewage which embraces—practically embraces all the different sewages of the United Kingdom—I think that will be a final opinion; I do not think there is any doubt about that.

3316. Have you thought out the arrangements that you would suggest for treating sewage in a volume of ten million gallons or twenty million gallons?—Certainly.

3317. What kind of trays would you suggest for such a purpose?—These trays at Caterham have been constructed to last as long as the barracks.

3318. Then you would multiply nests of that kind, would you?—Oh, certainly. I certainly would duplicate. I would have a unit, a convenient unit of construction, and go on indefinitely both as regards the tank and the trays.

3319. You are quite unable at present to suggest the cost of any of these units?—Quite; not that I would be long in ignorance.

3320. Can you tell us is your system protected in any way by patents?—Yes.

3321. Would there be any royalties in connection with its adoption?—I have got a series of patents, one of them deals with the particular construction of "the Cultivation" tank, that is the first: the second one deals with the question of duplicating or grouping bacteriological tanks for the purpose of obtaining nitrification, and so on. Then the next patent deals with the protection of this sequence of changes from the aërobic action of mixed organisms that come from sewage to a protected colony of organisms that are to carry on the final work of nitrification with another patent for the particular arrangement of trays, so that altogether there are five of those patents.

3322. Then in regard to the patent rights for the first portion, is it not a fact that upward septic filtration has been experimented on for some years?—The claim is for this specific apparatus as shown.

3323. But upward filtration of an anaërobic character through material which is coarse at the bottom and gradually becomes finer has been carried on has it not for some years?—I do not claim that in any way.

3324. Then what is the special claim in regard to the first part?—The specific form of apparatus which is shown on the diagram.

3325. You mean that narrow grating?—Quite so, with sloping sides, and so on, the object being to provide the favourable condition of having no pockets unremoved, as it were, so that it may move away together, not leaving any portion behind it.

3326. Now that the installation at Caterham is in working order, shall you have regular analyses made, and will careful observations be made in regard to the removal of any sludge or matters?—Well, it is not for me to suggest, but all I can say is that the Caterham installation, I believe, provides all the conditions, I do not know of any condition that is absent there for a complete investigation, and the Royal Commission are quite welcome to the use of it in every way.

3327. (*Dr. Russell.*) Following that question of Colonel Harding, have you made any provision at all at Caterham for the removal of sludge?—Well, the provision at Caterham for the removal of sludge does exist. It consists of a pipe carried—this is the arrangement practically at Caterham; as far as the tanks there is no penstock, there is a sump provided *here*. The sewage comes in *here*, and this leads into the grit chamber a pipe carried straight along *there*, which has a very rapid fall, and shoots out beyond the whole apparatus *here*, so that the cultivation tank, as a matter of fact, is commanded as you see by a penstock.

3328. Then what becomes of the sludge at that point?—Well, there is a ten-acre field there, and a very steep slope, and there it is.

3329. It would be spread over the field?—Well, as a matter of fact, there is a great deal of sand. I was led to understand that there was no surface water came into the installation, but there is surface water from the parade grounds, which is very sandy, and a great deal of sand is swept into that sump, and the instructions with regard to Caterham are that this penstock is to be opened once a week while they can count about five or ten.

3330. In order to let the sludge out?—Simply to keep the sand and stuff at the bottom of the sump on the move, and to remove the inorganic detritus; for about five seconds the instructions are that it should be opened.

3331. (*Colonel Harding.*) Is no note taken of the volume so removed?—No; it would be easily calculated from the head of the pipe; a five-inch pipe at a certain head. That could be very easily given, of course.

3332. (*Chairman.*) At Caterham have you any trade refuse to deal with?—Oh, none whatever, except the extraordinary things that come down from a barracks.

3333. But you have not had any experience anywhere of dealing with trade refuse?—I am not an expert at all upon that point. No, I have got no expert evidence in regard to that. I may refer you to Dr. Rideal's paper on the subject, read at the late Congress at Birmingham.

3334. (*Dr. Russell.*) What was the cost of this installation at Caterham?—I am not prepared to say that. I really do not know.

3335. At whose expense was it put up?—Practically at my own expense.

3336. It is a very important question, of course; you cannot say anything about the structural cost?—No. Of course that information will very soon be available. To be on the safe side the installation is too large.

3337. Is it a business arrangement that you have with the War Office?—No.

3338. You simply *ex gratia* are allowed to experiment there?—That is so, and no expense has been spared at all. I mean to say it is none the less complete because of no arrangement having been made.

3339. You have spared no expense?—No.

3340. Then what working attention have you got; what staff have you got in regard to sewage works?—When it is completed there will be no attention required at all except once a week for half an hour; something of that sort.

3341. I think you dropped a remark about a sewage farm or land of some kind upon which if it were not for your apparatus the sewage would be discharged?—Quite so. Well, there is a field, it is let to a farmer, who makes the most he can out of it. There is a small piece of grass land and a piece of ploughed land. It has a deep chalk undersoil and a very thin soil.

3342. Is it on this field the sludge is deposited?—Well, the sludge is simply discharged, as I say, for a few seconds

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every week to keep the inorganic detritus on the move. It is not with the object of removing any body of sludge, because there is no organic sludge to speak of. Of course, the sand is an important thing to get rid of. I suppose there may be a barrow load of sand at the end of a week; very likely there is, or more—two barrow loads of sand perhaps.

3343. And do you deal at all times with all the sewage of these barracks?—The entire sewage, yes.

3344. No portion of it flows direct to any outfall?—Oh, dear, no. I mean to say that during our experiments, as I have explained to the Commission, I have had all sorts of arrangements for allowing the sewage to come in at certain times of the day, so as to get it stronger than at others and so on, but I mean to say the apparatus is designed for taking the whole of the sewage and to spare; there is no doubt about that.

3345. Then I gather that it would be an essential part of your scheme that there should be a separate system of sewage?—Well, I think I prefer it as most people would, but apparently I do not think it will make very much difference. Of course, if you get an enormous amount of storm water you have got an enormous provision to make for it; there is no doubt about that. I mean to say the relation between the normal and the storm water may be anything, as you know, sir.

3346. Is there any community, any local authority, that has adopted your system?—No; there is no reason why they should, because it is only within the last twelve months that I myself have been in any way satisfied that I have approached finality in the results. I mean to say I was carried away to a certain extent, or thought perhaps too much of the results obtained at Ashtead six years ago, but that is hardly to be wondered at, because the results at that time were certainly somewhat startling, and I have explained the position with regard to the view the chemist took, and so on.

3347. And these plans do not represent anything that actually exists; they are more to explain a theory?—Quite so; they were designed for the paper that I read at Birmingham, but all the information with regard to Caterham, of course, with regard to cost and everything else, as soon as I can give it I shall have great pleasure in doing so.

3348. (*Chairman.*) Have you provided any storm overflows at Caterham?—Quite lately I have. I do not know what the very latest provision is. I had a four-inch overflow, and I believe they have put in another four-inch pipe as an overflow, and it has been going full bore during some of these storms. Of course, it is all hydrolised; I mean to say there is no crude sewage gets over. It is all subjected to the first part of the treatment. The overflow takes place not from the sewer itself; there is not a leaping pipe or anything of that sort; it takes the whole of the sewage, only the whole of the sewage does not pass over the trays. It is all dealt with.

3349. The whole of the storm water goes into the cultivation tank?—Quite so, the whole of it, and there have been tremendous storms.

3350. At what point is this storm overflow put in?—As matter of fact, it is put in about *here*—the one I put in the other day (*indicating*). I believe one has been added the other day *here*, relatively to the other.

3351. (*Professor Foster.*) Did I understand that in these analyses on page 7, where, as Mr. Killick has pointed out to you, the albuminoid ammonia rose from the fifth tray onwards—did I understand that you thought that was due to interference in taking?—I think so; I cannot account for it in any other way.

3352. But there is no interference with the rise of nitrogen as nitric acid; there ought to be?—No; because that process might go on, you see, sir; that would not be interrupted.

3353. But I mean the nitric acid comes through the conversion, does it not, of your ammonia and your albuminoid ammonia?—Yes, but, in disturbing the coke, in taking the sample, you might have some flocculent matter carried away, so that would not have appeared in a nitrogen change in any way; it would simply have stuck to the coke, you see, and nitrogen change would go on independently of any disturbance. For instance, supposing *this* was a tray on which a nitrogen change was going on, and you got an increase of albuminoid ammonia here, it might arise from your having—in taking the plate out *here*—started some flocculent matter from the trays above.

3354. In taking the plate out?—In taking the plate out; the plate or dish used for taking the sample coming away from *there* might affect the one *here*, you see.

3355. I may be wrong, but it is very unlikely that the nitric nitrogen should go on increasing and that the albuminoid ammonia should increase; it is not reasonable at all.

3356. (*Dr. Russell.*) If these are proper explanations of these peculiarities to which Professor Foster points, does not the ultimate result come to this, that the table of analyses is of no value whatever?—Well, you try that question with Dr. Rideal, and see what he says; I did not take them.

3357. It is a very natural question?—Yes. I think, probably, he will have an answer ready for that.

3358. (*Professor Foster.*) In your cultivation tank the nitrogenous matter is to a large extent brought to the condition of ammonia?—In the first tank?

3359. In the first tank; in your cultivation tank?—Yes.

3360. What becomes of the carbon elements of the organic matter?—They are converted.

3361. I mean, what gases are given off by your cultivation tank?—If you will kindly turn to page 9, you will find an analysis by Sir Edward Frankland; that has dealt with the carbon there.

3362. Yes. My question was what gases are given off in your cultivation tank?—I should think that all the experiments with regard to Exeter made by Dr. Rideal upon the gases there would apply, no doubt. I don't think there is reason to suppose that there is any difference.

3363. That similar gases are given off?—That similar gases are given off; but, you see, these analyses are confirmed by others. If you kindly refer to the last page, Dr. Russell, there is one in which the albuminoid is given as ·075 by an independent analysis, and Sir Edward Frankland does not give the albuminoid ammonia, but he gives the organic carbon as ·713—a fall from 5·538.

3364. You have said, I think, trying the liquefaction of your domestic sewage by the contents of the cultivation tank?—Yes.

3365. That it was so rapid that you thought it must be due to the action of enzymes?—Yes.

3366. Have you any observations to control that?—No.

3367. It is simply a suggestion?—It gave me a start; there is a great deal to be done, and one cannot do everything. Of course, the direct action of these enzymes will be a very interesting subject no doubt; and if that experiment was of anything like the importance it seemed to be, of course, it is very interesting to pursue it.

3368. I gather that the whole of the system is based on this, that sewage naturally contains all the organisms which under suitable conditions will bring down the whole of the sewage to carbon dioxide and nitric acid?—Quite so.

3369. And your arrangement is one for cultivating them successfully?—That is so.

3370. You think at first there should be some amount of organic change corresponding to the slight amount of oxygen which is present in ordinary sewage?—I think there must be, that you cannot avoid it. That would be the condition precedent to any control arrangement of any sort. The oxygen in the original water supply will be used up.

3371. Then after your organic changes which lead, in the end, to ammonia, either completely or nearly completely, you pass it through your successive trays?—Yes.

3372. By a kind of natural selection you obtain in each successive tray a form of nitrifying organism under the best circumstances to deal with the amount of ammonia which is left in the sewage when it reaches that tray?—That is so, and that, of course, is automatic. The survival takes place strictly in relation to the environment, and obviously the more equable that environment is the better results are likely to be obtained.

3373. Has Dr. Sims Woodhead, who has assisted you you said, made any examination of the fauna?—He is now engaged upon a series of experiments with the fauna of Ashtead and Caterham, and he has obtained from a small apparatus there a special cultivation of a bacillus, an Ashtead bacillus, an increase of 100 per cent. in nitrogen in twenty-four hours on its own sterilised sewage; but he says he expects even greater results from some of the cocci.

3374. Has he examined any of your nitrifying trays?—Oh, yes; these are the nitrifying trays to which I have referred. Then the effect of these very highly anaërobic changes which I refer to with the gases occluded in the inverted earthenware pots, has been apparently to immensely limit the variety of the fauna coming over from the anaërobic fermentation; that is to say, in the fourth tray, after an experimental bed had been working at Caterham for some time, I cannot give the time exactly, he discovered that there were neither bacilli nor bacteria there at all.

3375. When you speak, as I think you do, of the possibility of your anaërobic action being too great, do you mean that it produces undesirable ammonia compounds?—I divide that into two points in my evidence, sir. Obviously, you may have the ammonia too high for the work of nitrifying organisms.

3376. What is the evidence of that?—Well, I do not say that I have yet obtained it from sewage, or I do not say that sewage may produce it; but there may be something in that direction which I have not been able to identify. All I can say is that taking one thing with the other, I have arrested the whole process, and brought it to a standstill by carrying the anaërobic change too far. That I have succeeded in doing, and Dr. Rideal, as a matter of fact, is engaged upon——

3377. But that you thought it might be that you had, so to speak, suffocated the nitrifying organisms, and killed them by suffocation?—Quite so, or the organisms possibly, that have a facultative capacity of surviving the first three or four boxes. That may be very essential to the action of the first three or four trays; that is to say, that the work of the first three or four trays may be of great importance although it is not done by specifically nitrifying organisms.

3378. Which tray was it; did you move one tray or more than one tray?—Removed two trays.

3379. Which two were they?—The seventh and the eighth in the place of the second and the third, I think it was.

3380. (*Professor Ramsay.*) Is the tank which we see under Section A B covered in?—It is at Caterham entirely; that is on account of frost.

3381. Is anything done with the gases which come off sewage; are they just allowed to escape?—Well, there is a chimney provided for their escape, and there will be further provision made where necessary. Of course, that protection would not apply to the cases of climates where there was no frost, but it may be an advantage to blow air in as well. However, as a matter of fact, at Caterham, we have got eight parts per 100,000 of nitrates, which, of course, points to a very fair amount of aëration.

3382. Yes; but I thought that was in the nitrifying part of the plant?—I beg your pardon, you refer to carrying off the gases from the cultivation tank.

3383. From the cultivation tank?—Well, it is an exceedingly interesting point that you have raised. The gases that arise, I think, in answer to another question, I stated were practically on the same footing as those which come off from Exeter and other similar putrefactive changes; but with regard to these cultivation tanks it has been an invariable experience that at the end of about a fortnight we have been able to predict three days of a bad smell, from two to three days of a very offensive smell, and that has also invariably passed off, and the only way that I can account for it is that probably amongst the top flints, you understand, the liquid is not oxidised there, the flints are raised above the top level of the liquid for the purpose of masking it, and apparently there is a sort of blanket, I fancy, of carbonic acid gas formed, and there it lies. At any rate, as a matter of fact, it does not smell at Ashtead even if you put your nose on it, nor anywhere else.

3384. (*Professor Foster.*) Those three days are at the initiation?—Yes, in about ten days or a fortnight. I have been able to predict it in every case. I have been able to say, "Now you will have a very bad smell for a few days."

3385. And that does not return?—That does not return, and that has been a universal experience, so that it may be that carbonic acid does not rise in sufficient quantities till a certain time, that when it does arise it forms a sort of blanket amongst the flints. At any rate the smell is not in evidence in any way.

3386. (*Professor Ramsay.*) You have no frothing at the top of your flints in any way?—No.

3387. Nothing visible?—No.

3388. Do you know that Dr. Rideal has been personally testing for those compound ammonias that you are speaking of?—Yes.

3389. He has found them?—Yes.

3390. And they are known to be toxic?—Yes, they are methylamine and tremethylamine.

3391. I had not heard of their being formed by such precipitation before?—And that no doubt is a series that is formed at a very advanced stage of the anaërobic fermentation apparently, but I think he has got some from the septic tank at Exeter as well.

3392. Has he proved that from absence of the anaërobic organisms?—No; but I think that they are destructive of all living plasm if there is enough of it; is that not so?

3393. Enough of it, yes; but the products of an organism would always destroy it if they accumulated in sufficient quantity?—Of course, I am not prepared to say that he does account for it. You see my position is this: it is very important from a commercial point of view, and also from the point of view of actual users of an apparatus of this sort that you should know the size of the apparatus you are going to supply in relation to any duty that it has to perform, and if I had not carried that anaërobic change too far one would naturally have been always asking the question, "Now if you carried it further, can you not do with fewer trays?" It was very important that one should know that there was some limit to this anaërobic change, because people might go off with the belief that you might do with very little nitrifying plant, which is of course expensive on a large scale.

3394. (*Major-General Carey.*) What relation does the capacity of that cultivation tank bear to the dry weather flow at Caterham, or any typical case?—Well, the arrangement was very much the same as that of Mr. Cameron's—24 hours' supply, but apparently the provision of the stones makes, I think, it possible for this capacity to be very considerably reduced, because very excellent results were obtained from the middle of the Caterham tank, which is 40 feet by 20. The tank at Caterham is 40 feet long by 20 feet wide, and very good results were obtained from the middle of the tank without use of the anaërobic pot chamber at all, so that it points to less than the 24 hour content being sufficient.

3395. And the filter is designed in the same way?—The filter was designed to take 24 gallons per square foot per 24 hours, and that gives a little over 1,000,000 gallons per acre per day, but it is going to do considerably greater duty than that.

3396. What determines the number of trays?—The standard of effluent that is wished to be obtained.

3397. You must decide that beforehand?—You must decide that beforehand.

3398. You cannot alter the number of trays afterwards?—You decide what standard of effluent you want; you have all your data with regard to the amount of purification required, the standard of chlorine contained in the sewage representing its strength, the unoxygenised nitrogen that is capable of being dealt with by a certain number of trays from experience, and so you get your whole data for any strength of sewage.

3399. If the effluent is not good enough, or if it does not come up to your expectations, you have no alternative; you can supply more trays, but not in that installation?—With regard to that point, which, of course, is a very important one, the margin of available oxygen in the nitrates must be a very large one, that is to say, that you must not only get an effluent that will not be subject to secondary putrefaction of any sort, or to any putrefactive changes, nor secondary anaërobic fermentation,

Mr. W. D. Scott Moncrieff. 14 Dec. 1898.

but you must also have one that is capable of clearing itself up with a margin; in fact, you want to have it better than a river, and the percentage of oxidised nitrogen to the residual unoxidised organic nitrogen from the Ashtead experiments is higher than the Thames at Hampton Court, so that it is better than the River Thames at Hampton Court from that point of view.

3400. Are the trays particularly liable to the action of frost?—Yes, I think they are.

3401. Would some protection be necessary?—Quite so.

3402. (*Professor Ramsay.*) Is there any particular provision for aerating the trays?—No; there is an air space between each.

3403. (*Professor Foster.*) What is the depth of the air space?—Two inches.

3404. (*Chairman.*) Do you consider that the more trays there are the better the purification?—Oh, certainly.

3405. I mean if instead of having 7 you had 70?—Quite so.

3406. It would go on for ever being better?—Well, until you got a condition in which you had possibly denitrifying organisms. You might have organisms of distilled water and things of that sort. I mean the survival would go on in relation to the environment indefinitely. I think there is no doubt about that; you cannot conceive of its being otherwise.

TWELFTH DAY.

Thursday, 15*th December*, 1898.

PRESENT:

The Right Hon. The Earl of IDDESLEIGH (*Chairman, presiding*).

Professor RAMSAY, F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Major-Gen. CAREY.
Mr. THOMAS WILLIAM KILLICK.
Colonel HARDING.
Dr. BURN RUSSELL.

Mr. F. J. WILLIS, *Secretary*

Mr. JOSEPH GARFIELD, called in; and Examined.

Mr. J. Garfield. 15 Dec. 1898.

3407. (*Chairman.*) You are Mr. Joseph Garfield, an Associate Member of the Institute of Civil Engineers and the engineer in charge of Sewage Disposal Works at Wolverhampton?—I am, my Lord.

3408. Perhaps you would make a short statement of what you claim for your system?—Yes, my Lord. The system of sewage purification which I have to explain to the Commission has for its object the purification of the liquid from subsidence or precipitation tanks or that from any other process removing suspended matter, in other words, it only deals with soluble organic matter or impurity. The system is the result of investigations undertaken to find a substitute for land filtration. It consists of intermittent filtration through fine coal. After trying a large number of substances I found coal possessed a special power of removing organic matter from solutions by chemical or physical action which I cannot at present explain—independent of any biological purification, which in the form of nitrification, I have found commenced and proceeded with greater facility and energy in filters constructed with coal, than with any other material. The above superior qualities of coal, coupled with its ready attainability and its cheapness, have made me adopt it as the best material for the purification of the Wolverhampton tank effluent, which, although a difficult one, it deals with most satisfactorily. The fine coal used is nearly a waste product at many collieries, and can be obtained almost anywhere at a reasonable cost. The peculiar feature of coal is that the effluent from a coal filter the first day it is started is particularly bright and colourless, void of smell, and carries no bead upon violent agitation. No other medium I have tried will give at once anything like such a good effluent, indeed the good appearance of a coal filter effluent is most marked over that of any other filter. The following analyses show that there is a very marked diminution in the quantity of oxygen absorbed, although the organic ammonia is not reduced in the same degree, suggesting that the organic matter, removed immediately by the coal, is that portion most liable to decomposition:

Analyses of effluents from filter just started:—

	Organic Ammonia.	Oxygen absorbed in 4 hours at 80deg. F.
	Grains per gallon.	
Tank effluent - - - -	0·456	3·162
Filtrate - - - - -	0·072	0·238
Percentage purification - -	84·3	92·5

There were no nitrates in either sample.

After nitrification has set in, more nitrogenous organic matter is removed. The figures of analyses set forth in detail are as follows:—

WOLVERHAMPTON SEWAGE.

DETAILS of ANALYSES of EFFLUENTS from PRECIPITATION TANKS and COAL FILTERS.

Grains per Gallon.

Samples Collected.	Effluent.	Free and Saline Ammonia.	Organic Ammonia.	Oxygen absorbed in 4 hours at 80° F.	Nitric Nitrogen.	Combined Chlorine.	Per Cent. Purification on Organic Ammonia.	Per Cent. Purification on Oxygen absorbed.
1896:								
23 Jan.	Tank	6·229	0·456	3·162	0·0	25·27	—	—
	Filter	5·604	0·072	0·238	0·0	23·17	84·3	92·5
7 July	Tank lost		0·337	4·967	None	20·58	—	—
	Filter	4·004	0·098	0·236	None	18·76	71·0	95·3
28 July	Tank	No sample.						
	Filter	1·477	0·038	0·274	0·83	15·61	—	—
11 Aug.	Tank	No sample.						
	Filter	1·870	0·034	0·191	0·88	16·87	—	—
6 Oct.	Tank	No sample.						
	Filter	2·804	0·035	0·158	0·42	17·15	—	—
19 Oct.	Tank	No sample.						
	Filter	2·802	0·045	0·221	0·45	12·53	—	—
25 Nov.	Tank	No sample.						
	Filter	3·505	0·057	0·221	0·35	18·48	—	—
1897:								
3 Feb.	Tank	1·867	0·169	0·974	0·826	8·54	—	—
	Filter	1·868	0·030	0·155	0·875	8·33	82·3	84·0
16 Feb.	Tank	3·308	0·218	1·602	0·154	10·15	—	—
	Filter	2·338	0·055	0·223	0·994	10·36	74·8	86·1
8 Mar.	Tank	3·486	0·233	1·245	0·154	9·73	—	—
	Filter	2·325	0·056	0·197	0·343	9·59	76·0	84·2
5 May	Tank	4·012	0·334	3·361	None	13·58	—	—
	Filter	2·335	0·063	0·334	1·17	15·40	81·2	90·2
11 May	Tank	4·668	0·366	5·067	None	15·47	—	—
	Filter	2·912	0·052	0·281	1·17	15·68	85·8	94·5
14 July	Tank	3·490	0·221	3·000	None	12·60	—	—
	Filter	0·015	0·022	0·737 Much nitrite.	2·19	15·40	90·1	75·4
26 July	Tank	3·794	0·158	1·573	None	16·38	—	—
	Filter	0·005	0·023	0·151	2·80	14·21	85·5	90·4
6 Sept.	Tank	1·580	0·13	6·758	0·21	6·37	—	—
	Filter	0·350	0·021	0·130	1·00	6·72	83·9	82·9
1898:								
1 Mar.	Tank	2·916	0·349	1·21	0·10	12·11	—	—
	Filter	2·333	0·051	0·227	1·03	16·73	85·4	81·3
5 May	Tank	4·998	0·302	1·587	None	—	—	—
	Filter	1·400	0·042	0·237	2·80	—	86·1	85·1
20 June	Tank	4·487	0·243	0·990	None	11·83	—	—
	Filter	0·796	0·038	0·207	1·67	11·90	84·4	79·1
11 Aug.	Tank	5·147	0·346	6·777	None	20·58	—	—
	Filter	1·000	0·041	0·262	1·4	18·20	88·2	96·2
14 Sept.	Tank	5·457	0·370	3·213	None	26·32	—	—
	Filter	0·697	0·044	0·292	2·55	20·58	88·1	91·0

E. W. T. Jones, F.I.C.

Mr. J. Garfield. 15 Dec. 1898.

Dr. A. Bostock Hill, County Analyst, Birmingham, concludes a paper, which he read on "Filtration of Sewage through Coal" at the Congress of the Sanitary Institute in 1897, with the following:—"I submit, therefore, that in coal we have a filtering medium which produces a result far better than that claimed for other media. It is superior to coke, breeze, or ballast, in that it has at once a chemical action, and its purifying power is marked from the first day it is used, although a still better result is obtained after a period of two or three months' use. The medium is cheap and easily obtained, and although in the past I have looked upon filtration of sewage, otherwise than through land, as of partial and limited value, I strongly believe that the death knell of the costly sewage farm has been rung, and what is of far more importance from an economic and sanitary sense, the problem of sewage disposal has been at last solved, and the prevention of pollution of our rivers and streams has become, not only possible, but practicable."

Then follows details of analyses of Lichfield effluents as follows:—

LICHFIELD SEWAGE.

ANALYSES of EFFLUENTS from PRECIPITATION TANKS and COAL FILTERS.

Parts per 100,000.	17 March 1897.		24 March 1897.		31 March 1897.		7 April 1897.	
	Tank.	Filter.	Tank.	Filter.	Tank.	Filter.	Tank.	Filter.
Free Ammonia	0·412	0·400	1·00	0·30	0·75	0·42	0·875	0·40
Alb. Ammonia	0·062	0·030	0·15	0·058	0·12	0·028	0·130	0·036
Chlorine	5·1	12·0	6·0	7·4	6·1	6·5	5·7	6·5
N as Nitrate	0·44	0·33	—	1·07	—	0·35	—	0·33
O absorbed 4 hrs. 80 deg. F.	0·424	0·131	1·24	0·14	0·676	0·268	0·952	0·202
Total Solids	68·	78·	70·	71·	70·	70·5	60·	64·
Odour	Slight	V. Slight	—	—	—	—	—	—
Appearance	Sl. Turbid	Brt. & Clr.	Sl. Turbid	F. Brt. & Clr.	Sl. Turbid	Brt. & Clr.	Sl. Turbid	Brt. & Clr.

Parts per 100,000.	14 April 1897.		30 April 1897.		8 May 1897.		9 September 1897.	
	Tank.	Filter.	Tank.	Filter.	Tank.	Filter.	Tank.	Filter.
Free Ammonia	1·02	0·431	1·56	0·081	2·371	0·104	0·940	1·016
Alb. Ammonia	0·04	0·025	0·230	0·025	0·342	0·048	0·192	0·072
Chlorine	5·4	5·9	6·9	7·4	7·7	7·7	5·4	32·9
N as Nitrate	—	0·44	—	0·88	—	1·23	—	—
O absorbed 4 hrs. 80 deg. F.	0·2	0·16	1·08	0·12	1·82	0·2	0.95	0·285
Total Solids	66·	68·	64·	70·	69·	77·	51·	118·
Odour	—	—	S.S. Bry. refuse.	None	S.S. Bry. refuse.	None.	S.S. Brt. refuse.	None.
Appearance	Sl. Turbid	F. Brt. & Clr.	Sl. Turbid	Brt. & Clr.	Sl. Turbid	Brt. & Clr.	Sl. Opal	V. Slight. New Filter.

A. BOSTOCK HILL.

Dr. Hill, writing on October 17th this year says: "Since the analyses were published further experience has shown me how valuable coal (properly used) is as a purifying medium for sewage." The following figures are taken from a report to the Staffordshire County Council, by the Medical Officer, Dr. George Reid, on "Sewage Disposal at Tipton." "Experimental Filters."

—	Organic Ammonia.	Oxygen absorbed in 4 Hours at 80 deg. F.	Nitric Nitrogen.
		Parts per 100,000.	
Tank effluent	0·23	0·77	Nil
Coke breeze filter	0·16	0·58	0·38
Garfield's coal filter	0·04	0·20	0·81

Percentage Purification.

On Organic Ammonia Basis.

Coke breeze filter	33·2
Garfield's coal filter	80·6

On Oxygen Absorbed Basis.

Coke breeze filter	29·0
Garfield's coal filter	70·8

Dr. Reid says: "When the Tipton experiments were first started the only knowledge we had of coal as a filtering medium was that derived from the working of the experimental filter at Wolverhampton. Since then, however, coal filters, on a comparatively large scale, have been constructed in other districts in this county and in Derbyshire with uniformly excellent results."

Details of the analyses of effluents at Tipton are as follow:—

SEWAGE FILTRATION AT TIPTON.

Mr. J. Garfield.

15 Dec. 1898.

DETAILS of ANALYSES of EFFLUENTS.

Parts per 100,000.

TANK EFFLUENT.

Sample Collected.	Solids.			Chlorine.	Free Ammonia.	Organic Ammonia.	Oxygen absorbed in 4 hrs. at 80° F.	Nitric Nitrogen.	Depth at which test lines are obscured.
	In Solution.	In Suspension.	Total.						
1896.									
8 Sept.	73·0	6·0	79·0	9·2	1·760	0·299	1·600	Nil.	1·5
19 Oct.	84·0	Nil.	84·0	10·2	1·640	0·196	0·696	Nil.	4·0
4 Nov.	87·0	Nil.	87·0	10·6	1·660	0·304	0·888	Nil.	3·5
1897.									
11 Jan.	94·0	Nil.	94·0	10·0	1·619	0·108	0·520	Sl. Trace	7·5
8 March	92·0	1·0	93·0	10·2	1·536	0·270	0·752	0·05	4·0
6 March	102·0	Nil.	102·0	11·0	1·078	0·112	0·500	Trace.	14·0
30 March	93·0	Nil.	93·0	10·8	1·176	0·132	0·584	Nil.	8·0
21 April	87·0	4·0	91·0	10·2	1·153	0·297	0·972	Nil.	4·0
17 May	75·0	3·0	78·0	11·0	0·885	0·234	1·060	Nil.	3·5
9 June	72·0	Nil.	72·0	9·6	1·016	0·256	0·440	Nil.	4·0
14 June	69·0	Nil.	69·0	10·0	0·936	0·171	0·344	Nil.	15·0
19 July	68·0	7·0	75·0	11·0	0·840	0·506	1·168	Trace.	2·5
28 Sept.	79·0	Nil.	79·0	9·4	0·977	0·147	0·580	Nil.	14·0
Mean	82·7	1·6	84·3	10·2	1·25	0·23	0·77	Nil.	

COKE BREEZE FILTER.

1896.									
6 Sept.	70·0	Nil.	70·0	8·8	1·760	0·219	0·668	Nil.	4 inches.
19 Oct.	87·0	Nil.	87·0	9·8	1·300	0·144	0·468	0·10	5 „
4 Nov.	89·0	Nil.	98·0	10·4	1·560	0·254	0·640	Nil.	3·5 „
1897.									
11 Jan.	94·0	Nil.	94·0	10·2	1·344	0·092	0·440	0·35	7 „
30 March	97·0	Nil.	97·0	10·8	0·666	0·077	0·368	0·42	9·9 „
21 April	88·0	Nil.	88·0	10·0	0·791	0·210	0·944	0·41	5 „
17 May	76·0	2·0	78·0	10·6	0·733	0·196	0·872	0·41	7·5 „
9 June	75·0	2·0	77·0	9·4	0·468	0·156	0·360	0·42	5·5 „
14 June	70·0	Nil.	70·0	9·8	0·368	0·126	0·360	0·61	over 2 ft.
19 July	74·0	5·0	79·0	10·8	0·032	0·200	0·748	1·11	6·0 inches.
Mean	84·0	0·9	84·9	10·0	0·90	0·16	0·58	0·38	

"GARFIELD" COAL FILTER.

1897.									
6 March	113·0	Nil.	113·0	12·8	0·740	0·030	0·116	0·10	over 2 ft.
30 March	96·0	1·0	97·0	11·0	0·475	0·042	0·236	0·55	„
21 April	103·0	2·0	105·0	11·0	0·012	0·024	0·172	0·95	„ „
17 May	101·0	Nil.	101·0	11·0	0·064	0·037	0·200	2·08	„
9 June	81·0	Nil.	81·0	9·4	0·004	0·043	0·120	0·87	15·5 inches.
14 June	79·0	Nil.	79·0	10·0	0·135	0·058	0·184	0·61	over 2 ft.
19 July.	77·0	Nil.	77·0	10·8	0·108	0·088	0·348	0·39	12·5 inches.
28 Sept.	81·0	Nil.	81·0	9·2	0·025	0·042	0·272	0·95	over 2 ft.
Mean	91·4	0·3	91·7	10·6	0·19	0·04	0·20	0·81	

Mr. J. Garfield.

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	Percentage Purification.	
	On Organic Ammonia.	On Oxygen absorbed.
Coke Breeze - - -	33·2	29·0
Garfield's Coal - -	80·6	70·8

Geo. Reid, County Medical Office.

The following is an extract from a book on "The purification of Sewage," by Dr. Sidney Barwise, Medical Officer of Derbyshire County Council, page 131: "The following are some results obtained with coal, destructor breeze, and coke breeze filters at Buxton:—

Filter.	Parts per 100,000.			
	Tank Effluent.		Filtered Effluent.	
	Organic Ammonia.	Nitrogen as Nitrates.	Organic Ammonia.	Nitrogen as Nitrates.
Destructor breeze -	0·23	Nil	0·10	0·10
Coke breeze - -	0·23	Nil	0·11	0·09
Coal - - -	0·23	Nil	0·05	0·42

3409. (*Dr. Russell.*) Are these all places where your process has been carried out?—Yes, sir.

3410. Coal filtration?—Coal filtration.

3411. (*Colonel Harding.*) Following precipitation?—Following subsidence, or any other process removing suspended matter. It is a fine filter; it is not a coarse filter. In the case of Tipton, where the experiments were carried out by Dr. Reid, Medical Officer of Health of the Staffordshire County Council, the sewage is precipitated by lime, and the tank effluent put on to the coke breeze filter and Garfield's coal. It is a weak sewage. "In addition to being tried at Buxton and Tipton, coal filters have been tried at Lichfield, Chesterfield, and Kimberley with equally striking results. Effluents such as those from the coal filters at Tipton and Buxton, containing a large quantity of nitrates and little organic ammonia, are practically perfect."

Construction of Coal Filter.—The depth of filtering media should be 5ft. where possible. The whole of the coal used (except a little over and about the under drains) will pass a 3-16th inch mesh. This is divided into two sizes, which I call ⅛ inch cubes and 1-16th inch cubes. The fine dust and dirt being removed, the 1-16th inch cubes form the top layer of the filter. The liquid to be purified is distributed over the surface of the filter by means of open gutters or perforated pipes. Percolating slowly through the bed of coal the liquid, on reaching the underdrains, is at once discharged. The effluent drains being always kept fully open it is not necessary to make the filter tank watertight. *Cost.*—It must be remembered that the sewage to be treated must have undergone a process of clarification for the removal of suspended matters, and in some cases to be chemically treated before being applied to the filters, as when it contains strong galvanising pickle. Excluding this preliminary treatment the capital cost varies, as the site is near to or far away from a colliery, from £3 to £5 per 1,000 gallons per day, no brickwork or concrete being used in the construction of the filters. These filters have been constructed at a cost of 33s. per 1,000 gallons per day, and on the other hand filters to deal with a very small volume of sewage have cost £11 per 1,000 gallons per day. In this latter case brickwork was used in the construction of the filters. *Current Cost.*—My filters not having been in operation more than two and a-half years it is not possible to give any exact figures for the current cost. Up to the present time the current cost is about 1s. 6d. a year per 1,000 gallons treated daily. *Admixture of Trade Refuse.*—If the trade refuse be mineral, it would not affect the cost, as it would have to be removed by the preliminary treatment. If excessively organic, the area of filters would have to be increased in proportion to the strength of the sewage mixed with the trade waste. This would also increase the current cost in proportion to the increase in filter area. In conclusion I should like to point out that a very high degree of purity has been aimed at, and to obtain this the rate of filtration has, in most cases, not exceeded one million gallons per acre per day.

3412. (*Chairman.*) As I understand nothing gets on to these filters except sewage that has been previously prepared in some way?—Yes, my lord.

3413. No solid sewage gets on to them at all?—No solids in suspension; all solids in suspension are removed.

3414. And may I ask whether the sewage in your filters does not tend to make channels for itself, or how you prevent it doing so?—The sewage on the surface does tend to make channels, and to avoid that the filter is forked over once in three to six weeks. That is the chief expense in maintaining the filter.

3415. Where is the principal place in England that the system is in force now, that it could be best seen?—At Wolverhampton, or it is at Lichfield, where, in a month's time, there will be 1,600 yards of new filter started.

3416. I suppose the Commission could see it if they wanted to?—Certainly, my lord.

3417. And what sort of population will that deal with at Lichfield?—A population of 5,000, my lord.

3418. Have you any samples of the filter effluent which have been kept for a long period and then analysed?—I have kept samples for more than two years. I have no analyses of the samples after they have been kept that period; but they have shown no signs of secondary decomposition or putrefaction whatever during the whole time.

3419. (*Colonel Harding.*) The size of material that you use being 1-16th of an inch would be quite different, would it not, from that of coke filters with which you are making comparisons?—It would be smaller, sir.

3420. Much smaller?—It would be much smaller.

3421. What would be about the size of the coke with which you are comparing?—About ¼ of an inch.

3422. And was the coke filter being used in the same way as your own by continuous action?—In the first case it was used by filling the filter tank full of water, and allowing it to stand for two hours, and then run off, but for the second period of time it was used continuously the same as the coal filter.

3423. With about the same flow?—Exactly the same flow.

3424. Then you have not given any explanation of the action of the coal filter, but you rather suggested that it might be chemical?—It was Dr. Hill who suggested that it was chemical. I was quoting from Dr. Bostock Hill at that time. For myself I do not know how to explain it at all.

3425. But you have dug down into your filters, have you not?—Dug down several times.

3426. And they have been at work over two years?—Yes.

3427. Well, have you been able to notice any change in the appearance of the coal; has there been any disintegration of the coal?—I have noticed no change, or any disintegration whatever, three or four feet down the filter.

3428. And that would lead you, would it not, to conclude that there probably was no chemical action, possibly a mechanical, or, it may be, a biological?—There is some action takes place before biological action; but whether it is chemical or purely a physical action I cannot say.

3429. You had no experiments made with the micro-

scope or otherwise to find out what the bacterial conditions were of the filter?—None at all, sir. That is when it was first started.

3430. (*Dr. Russell.*) What is the construction of your filters? I mean have you a brickwork case?—It is not necessary to have brickwork, neither is it necessary to have the tank watertight. The filter is never filled with water, it is percolating slowly from top to bottom the whole time.

3431. Practically it is a hole in the earth?—Practically a hole in the earth, yes.

3432. Is that actually the nature of the filters that you have in operation at Wolverhampton?—The filter in operation at Wolverhampton is brickwork.

3433. (*Colonel Harding.*) Have you at the side of your filters any drain pipes or any means of aeration?—I have experimented with that, sir, but I have abandoned them.

3434. You have found that to artificially bring air to the bottom of the bed was not necessary?—I found that it was better for the air to pass down through the filter itself, as the water was passing on to it in the continual working.

3435. (*Dr. Russell.*) In these other places—Burslem, Tipton, Chesterfield, Lichfield—have they got brick tanks, or are they holes?—Burslem? I cannot say at Burslem; Buxton has brick; Chesterfield has brickwork; Fenton has brickwork; Honington brickwork; Kimberley has earthwork; Malvern has brickwork; Tipton brickwork; Tunstall brickwork; and Wolverhampton brickwork.

3436. So that in the majority, as a matter of fact, they are brickwork tanks?—Those are on a small scale, and they found it advisable to construct the brickwork round. At Lichfield the experimental tank is brickwork, the tanks which they have constructed now are earthwork.

3437. What is the nature of the surrounding soil; what demarcates the portion that you call "filter" from the portion that is practically the native earth?—There is practically no dividing line, sir.

3438. Does the filtrate from those holes go right away; how is it collected?—It is collected by under-drains. The bottom of the earthwork dug out is under-drained and the bottom of the filter is made to slope to the under-drain and the earthenware pipes are carried directly under the embankment, and out either into the watercourse or on to a field, as in the case of Lichfield.

3439. Then when you say "bottom" you really mean the place where the coal stops, and where the earth begins?—That is so.

3440. Then you say that the action seems to be immediate, that is to say that you run on your precipitation effluent, or whatever it may be, and that at once you find that the filtrate is pure; it does not improve?—It improves at once, sir.

3441. Yes, but is it not imperfect at first, and improves in its action after a day or two or a week or two?—Yes, it improves when nitrification sets in.

3442. So that whatever is the cause of the purification it is something that improves through use up to a certain point. It becomes more active through use, through the use of the filter?—The improvement I put down to nitrification.

3443. Well, I want to have first whether it is a fact that you have noted that the filtrate improves in its quality after the filter has been in use for a period?—It does.

3444. Of course, that is exactly what a biological filter does?—Certainly. With reference to that I should like to explain that the first action is very marked from ·456 organic ammonia in the tank effluent to ·072 the first day the filter started.

3445. Then you keep them at work continuously?—For twelve hours in the day and rest them for twelve hours in the day.

3446. Well, that is another biological feature?—Certainly, it is a purely biological filter.

3447. But I think you told us that you had not made up your mind whether it was mechanical or biological. I think you said so to Colonel Harding?—That is the peculiar action the filter has in the first instance before biological action sets in.

3448. Oh yes, I see; you start off with an amount of purification that you do not think biology will explain?—That is it, sir.

3449. Nevertheless, it is a purification that grows by use and requires aëration?—Certainly, sir.

3450. To keep it up?—Certainly, sir.

3451. (*Professor Foster.*) You have had no bacteriological examination made of your system?—No full bacteriological examination.

3452. Not at all?—Yes, I have one.

3453. To what extent?—Mr. Jones, the County Analyst of Staffordshire, made an examination, and he found the organisms that lived at blood heat reduced 99·7 per cent.

3454. There was a reduction of 99·7 per cent. of the organisms existing at blood heat, and present in your precipitation effluent?—Yes.

3455. 99·7?—Yes, 99·7.

3456. Was that after the filter had been working for some time?—Yes, it had been working for more than six months; I cannot say exactly how long.

3457. You said, I think, on the first day there was a reduction in the organic ammonia to this extent that in the material thrown on the filter there was ·456?—That is so, sir.

3458. And that on the first day it was reduced to ·072?—Yes, that is so.

3459. At that time there was no nitrate at all in the filtrate?—No nitrate in the filtrate.

3460. Subsequently nitrates appeared in the filtrate?—Yes.

3461. And during that time what was the organic ammonia in the filtrate?—You say on the first day it fell to ·072, and subsequently improved; to what extent was the improvement; what was the further reduction in the organic ammonia?—·056, ·063, ·052, ·022, ·023, ·021, ·051, ·022, ·038, ·041, ·044.

3462. Your greatest is ·021?—That is the lowest figure.

3463. Then on that first day the ammonia must have been retained in the filter?—The organic ammonia?

3464. The organic ammonia must have been retained in the filter?—Certainly.

3465. But you have no view as to how it was retained?—No, I have not.

3466. (*Professor Ramsay.*) It is called albuminoid ammonia?—Albuminoid ammonia.

3467. There is only one question I wish to ask you; that is, is the filter full of liquid or does it dribble? Does the sewage that goes on to the filter fill it up, or is a large part of the filter filled with air?—A large part of the filter is filled with air the whole time.

3468. The whole time?—The whole time the filter is at work, and of course when it is resting as well.

3469. Have you any idea of the proportion of the filter that holds water?—I have no exact proportion.

3470. You could get at it, I suppose, from the area of the filter beds and the amount you allow to flow on?—I have done that in one case. That is, I back pounded the water in a small filter, the capacity of the tank was reduced one-half by the coal in it. It only held half as much water after it had been filled with coal as before.

3471. But you do not know how much of the filter when it is in action is filled with air, and how much is filled with water?—No, sir.

3472. Do you think it is a large amount?—Yes, I think it is a large amount. The sewage when working takes about three-quarters of an hour to go through, and in that time there has been about three inches depth of water run on the filter, so that I think you may say the whole filter contains what would form a depth of three inches on the surface.

3473. To be quite clear the water does not actually lie three inches deep on the surface, but supposing all that water were placed on the surface it would cover the filter to three inches?—It would cover the filter to three inches.

3474. (*Professor Foster.*) What is the size of the filter?—Five feet deep.

3475. (*Major-General Carey.*) Do you consider it absolutely necessary to shut off the filter for twelve hours in order to produce the results that you obtain?—It is absolutely necessary to give it some rest.

3476. Have you tried intermediate periods of rest?—I have.

3477. Quite so; one period of twelve hours?—At the

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present time we are working it at Wolverhampton four hours, and resting it four hours.

3478. At Wolverhampton?—At Wolverhampton at the present time.

3479. I understood that the sewage ran through for twelve hours, and was turned off for twelve hours; that that was the intermittent period?—That is the case in some places. In fact, with one filter at Wolverhampton that is the case now. Another filter is working four hours and resting four continually.

3480. And what difference is there in results?—I am unable to notice much difference.

3481. An intermittent filter for shorter periods of intermittency would enable you to pass more sewage through, would it not?—The total for the twenty-four hours is the same, sir, three periods of four hours resting and working.

3482. What is your maximum rate of filtration in gallons per square yard?—The usual rate is at the rate of 400 gallons for twelve hours, making a total for the twenty-four of only 200 gallons per square yard.

3483. I do not quite understand your Lichfield filters. I understand that they are 1,600 yards?—They are 1,600 yards.

3484. For a population of 5,000?—5,000; the population of Lichfield, I believe, is 8,000, but these 1,600 yards treat the sewage of about 5,000 of the population.

3485. About 150,000 gallons. Do you calculate it at thirty gallons per head?—We calculate to put on 200 gallons per square yard on the 1,600 square yards.

3486. That is 320,000 gallons per day?—Yes.

3487. As you only put it on for twelve hours, I suppose it would be 160,000?—No, sir; we put it on at double the rate while it is at work.

3488. My point is that taking 5,000 population at thirty gallons per head per day would only be 150,000 gallons per day; but as I understand you, you pass 320,000?—The total volume of sewage delivered at Lichfield is 500,000 gallons per day.

3489. On this filter?—No, at the sewage works.

3490. Oh, yes; I know you say a population of 5,000 treated on this filter, this coal filter, which is of an area of 1,600 yards, is not that so?—Perhaps I could better explain it in this way. The population of Lichfield is about 8,000, and the flow of sewage is 500,000 gallons per day. We have first put down 1,600 square yards to take 320,000 gallons of sewage.

3491. Yes?—The sewage contains a good deal of brewery waste, and is very strong, so that the population was not the basis taken.

3492. Is brewery waste the only refuse water that you have got to deal with?—The only trade refuse water, except from the slaughter-houses in Lichfield.

3493. And ordinary precipitation is sufficient; there is no chemical treatment?—Lime and alumina ferric.

3494. Before putting it on to this coal filter?—Yes, before putting it on to the filter.

3495. (*Colonel Harding.*) Just one question, Mr. Garfield. At Wolverhampton is the whole of the sewage at that place dealt with on your principle?—At Wolverhampton only a small volume of it.

3496. How much of it?—18,000 gallons a day at the present time.

3497. How is it that has not been extended in view of the experience you have gained in the last 2½ years?—They are about to extend it at the present time.

3498. How much?—Well, they propose to spend £500.

3499. How large will the area of the filters then be? Do not trouble to calculate it. Anyway, Lichfield would be a better place for us to go to than Wolverhampton, because we could see it on a larger scale?—On a larger scale.

3500. They have had more belief in you at Lichfield than at Wolverhampton?—Before I got this out they had just taken 300 acres, and they now have a farm of 600 acres for a population of 86,000.

THIRTEENTH DAY.

Tuesday, 17th January, 1899.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

Sir HENRY ROSCOE, F.R.S., D.C.L., LL.D., called in; and Examined.

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3501. (*Chairman.*) I think, Sir Henry Roscoe, you are a F.R.S., and Emeritus Professor of Chemistry in the Owens College, Victoria University, Manchester?—I was Professor for thirty years, and I am now Emeritus Professor.

3502. And you have for many years been concerned in questions of sewage treatment and sewage purification, and generally with questions affecting river pollution?—That is so.

3503. And I believe you were a member of Sir Charles Russell's Select Committee on the pollution of the river Lea in April, 1886?—Yes.

3504. And you were engaged professionally to report upon the operations carried on at the Sewage Outfall Works at Barking and Crossness of the London County Council under the late Metropolitan Board of Works?—Yes, that was so, in the years 1887 and 1888. In the latter year, however, that body ceased to exist.

3505. I understand that you have acted as Scientific Adviser to the Mersey and Irwell Joint Committee since its inception?—That is so.

3506. You are good enough to come here to-day to offer us some evidence as to the tests which you have applied to sewage effluents for the purpose of ascertaining whether they are harmless, and to what extent they could be purified?—Yes, these are the definite points upon which I am asked to give evidence. At the same time, the documents which I have prepared, and which I propose with your leave to submit in supporting my statement with regard to chemical tests serve further purposes, namely, in the first place, the consideration of the question of adopting standards, and in the second place the consideration of the results obtained from the various methods of sewage purification. I do not know whether that is the wish of the Commissioners to get my opinions on those latter points, or whether you desire I should confine myself solely to the question of the appropriate tests which are to

be applied to the examination of sewage and sewage effluents. I am ready to deal with the three points.

3507. May I ask if you have any papers which you would like to hand in?—I have a considerable number of papers which I think it might be desirable to hand in as giving the basis of the evidence which I propose to lay before you.

3508. Are those the papers described on the first page of this statement?—Yes, they are.

Documents put in:—

(1.) Report to the Metropolitan Board of Works on the treatment of London Sewage at the Outfalls during the year 1887;

(2.) Ditto during the year 1888;

(3.) Report to the Mersey and Irwell Joint Committee, dated November 5th, 1894, containing analyses of sewage effluents;

(4.) Ditto, dated December 6th, 1897, on the analyses of Waters of the Manchester Ship Canal;

(5.) Paper on the Chemical Bacteriology of Sewage. Transactions of the Royal Society, Vol. 182 (1891);

(6.) Report, dated September 7th, 1894, presented to the Rivers Committee of the Manchester Corporation on the Chemical Treatment of Sewage. Analyses of Sewage and Sewage effluents;

(7.) Report, dated April 14th, 1896, presented to the Rivers Committee of the Manchester Corporation, on Artificial Filtration. Analyses of Sewage, effluent after chemical precipitation, cinder filtrate, coke filtrate, and land filtrate;

(8.) Report, dated April 1st, 1897, presented to the Rivers Committee of the Manchester Corporation, on the Chemical Analyses of Tank effluent, cinder filtrate, and coke filtrate;

(9.) Report, dated June 18th, 1897, on the capacity of the Experimental Filter Beds referred to in Reports 7 and 8;

Appendix No. 18 (A).

(10.) Plan of Experimental Filter Beds referred to in Reports 7 and 8;

(11.) Analyses and Classification of Sewage effluents submitted for report by the Mersey and Irwell Joint Committee, January to October, 1898.

3509. You have been good enough to send us a statement of your evidence, which we have all had time to study, and I should now propose that we take the greater part of that statement as read, and proceed to ask the questions that it has suggested to us. In putting those questions points may arise upon which you may very likely wish to enlarge, and, of course, I need hardly say, we should be very glad to hear anything you may wish to say upon them?—Thank you, that course will be quite satisfactory.

3510. Then I propose that we take this statement as read down to page 16.

Character of Crude Sewage.

Crude sewage as it arrives at the Outfall Sewer contains liquid and solid excrement from men and animals, water contaminated with animal matter, soap, and materials used in the cleansing of the person and linen, liquid and solid vegetable matters derived from the preparation of vegetables, grease, undigested food, blood, dirty water from the cleansing of the household as well as other solid refuse. In addition to these liquids derived entirely from the conditions of domestic life, crude sewage may be and is frequently diluted and contaminated with the rain washings of roads containing detritus and animal matters, and in many cases, especially in towns, other important constituents are added to the sewage, viz., trade effluents from manufactories of varied kinds.

Decomposition of Sewage brought by living organisms.

The nature of crude sewage is therefore of a very complex and variable character. Whether it be derived from the smallest Urban District or the largest County Borough it possesses, however, certain common properties, inasmuch as the organic matters which are therein contained are liable to undergo putrefactive changes. These changes are brought about by living organisms. The products of this putrefactive change readily absorb free oxygen, passing into more stable forms, and therefore, when sewage is discharged beyond a certain proportion as compared with the river water into which it flows, the former robs the whole of the water of its dissolved oxygen, and the conditions brought about are such as to cause a liability to putrefactive decomposition.

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Part played by free oxygen.

Sewage is either entirely free from, or at any rate contains less dissolved oxygen than is necessary for the active growth of aërobic organisms, and in consequence of the absence of dissolved oxygen in the sewage, this has during its passage to the Outfall already begun to undergo change of a putrescent character owing to the growth of the anaërobic organisms, which is facilitated by the above conditions.

Anaërobic and Aërobic Organisms.

On the other hand, the life of the aërobic organisms which require free oxygen for their growth tends to render the organic matter inoffensive, the necessary oxygen being usually derived from the air dissolved in all unpolluted running waters. But should the river water either be insufficient in quantity or have lost its oxygen by previous pollution, then the whole volume of water, after mixing with the sewage, becomes incapable of supporting the life of the aerobic organisms, and the only natural remedy then remaining is the slow absorption of atmospheric oxygen at the surface of the water.

Vegetable Organisms.

But other organisms of a vegetable character, such as algæ, are present in river water. These evolve oxygen during their life, and they are also potent instruments in the natural purification of river water; indeed, they are capable of oxygenating the water far above its normal amount, and thus aiding in supporting the life and growth of the former class of organisms. Both forms, therefore, assist each other in ridding the water of dead organic matter both soluble and insoluble, and thereby bringing it into a healthy condition.

The importance of these considerations is well recognised, and was referred to by me in two reports presented to the Metropolitan Board of Works in December, 1887, and in December 1888, both of which I hand in.

Self-purification of River Water.

I might also add with regard to the action of algæ on water, especially in reference to the self-purification of rivers, that Professor Albert R. Leeds (*see* "Journal of the Franklin Institute" for March and April, 1878, reported in the "Chemical News," June 14th, 1878) discusses the recommendations of Mons. Gerardin, and calls attention to the self-purification of the River Vesle above and below the City of Rheims, where in the course of 37½ miles the river was observed to be clean, polluted, and clean again, its purification having been effected by natural agencies.

Then we have in Dr. Odling's evidence, given before the Royal Commission on the Metropolitan Water Supply, 1892, a succinct statement of the considerations of the part which these minute chlorophylls, or algæ, play in the purification of water (*see* "Minutes of Evidence," p. 382).

Chemical and Bacteriological Research.

A complete examination of the complicated questions involved in the action of the various organisms taking part in the natural purification of sewage is of paramount importance, but such an investigation, I need scarcely point out, is one not only requiring a considerable expenditure of time and labour, but involving one of the most delicate and difficult problems of modern science, as our knowledge of these actions is as yet incomplete.

The important part played by oxygen through the medium of microbic life in the disintegration of organic matter in water has been examined by a great many chemists in succession, and in a great variety of ways, and I have myself given some attention to the chemical bacteriology of sewage.

In a paper printed in the "Transactions of the Royal Society for 1891,' to which I would call attention, I have

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shown the rapid absorption of oxygen by certain organisms. The experiments are of interest as being the first in which the action of a number of pure cultures of the organisms isolated from crude sewage serving as typical examples of those usually present in sewage have been examined with regard to their chemical characteristics more especially as to their very remarkable power of absorbing oxygen. The results show that the various organisms examined exhibit great differences in their absortive power for free oxygen, some showing the feeblest absorption, whilst others abstracted nearly every trace of oxygen from an atmosphere ten times as large as the culture liquid during seven days' incubation at 68° to 74° Fahr. Thus for example, an organism "Bacillus opalescens," classed as Anaërobic, which occurred plentifully in the sewage experimented with, gave the following absorption of oxygen :—

Absorption of free Oxygen from Air by various organisms.

25 c.c. sterile broth, 250 c.c. air. { With trace of pure culture in sealed flask.

After seven days the atmosphere possessed the following composition :—

Nitrogen	80·0
Oxygen	13·3
Carbonic Acid	6·3
Oxygen absorbed	6·7

pure air being represented by—

Nitrogen	80·0
Oxygen	20·0

That is to say, 16·75 c.c. oxygen (0·37 grain) was absorbed from 250 c.c. air containing 50 c.c. oxygen (1·10 grains).

On the other hand, an organism classed as Aërobic, "Bacillus fluorescens liquefaciens," which also occurred plentifully in the sewage, abstracted nearly all the oxygen in three days, whilst no trace of oxygen was found after seven days.

Absorption of Dissolved Oxygen by various organisms.

Again, the rate of absorption of dissolved oxygen is very rapid in the case of those organisms which absorb oxygen rapidly from the air. For instance, to a Winchester quart bottle of sterilised aerated water at 69° to 71° Fahr. was added 1 per cent. by volume of broth which had been sown with a minute trace of a pure culture (Bacillus violacens) two days previously, and incubated at 69° Fahr. The original volume of oxygen dissolved was determined and found to be 6·04 c.c. per litre (0·134 grain). After three hours incubation at 69° to 71°, the oxygen remaining was 5·6 c.c., whilst after 21 hours all but a trace of oxygen (0·2 c.c.) had disappeared. Subsequent experiments show that an incubation of 14 hours was sufficient in the case of those organisms which absorb oxygen rapidly to ensure the disappearance of all but a trace of the oxygen originally dissolved in the liquid, whereas others which do not absorb oxygen so rapidly by the air method show a corresponding difference by this method.

Conclusions arrived at.

The conclusions arrived at in this research may be shortly stated :—

(*a*) Of 12 organisms studied, five are capable of growing in complete absence of free oxygen, viz. :—

Anaërobic organism :

1. Proteus vulgaris.
2.
3. Streptococcus mirabilis.
4. Bacillus opalescens.
5.

Whilst to the other seven free oxygen is a necessity, viz. :—

Aërobic organism :

1. Bacillus fluorescens non-liquefaciens (*a*).
1. Ditto (*b*).
2. Bacillus fluorescens liquefaciens.
3. Bacillus subtilis.
4. Bacillus violacens.
5. Streptococcus ureæ.
6. Micrococcus.

(*b*) Of the Anaërobic organisms, one only, Proteus vulgaris, shows a vigorous absorption of oxygen, and this is the one which gives rise to offensive decomposition of the nutrient material.

(*c*) Of the seven Aërobic organisms, five are rapid absorbers of that gas, whilst two, Streptococcus ureæ and Micrococcus, absorb oxygen much less rapidly.

Corroborative evidence as to the purification of contaminated water by natural agencies.

If further evidence be required as to the importance of organisms (requiring and absorbing free oxygen) as a means of slow combustion and destruction of the organic matter of sewage. I cannot do better than refer to the evidence of Dr. Odling, who, in a clear and luminous statement given in his evidence before the Commission on the Metropolitan Water Supply on page 380 of the minutes of evidence, points out how river water contaminated with sewage matter is purified by natural agencies.

Indeed, so long ago as 1868, Sir Edward Frankland admitted that the "oxidation of the organic matter in water is effected chiefly, if not exclusively, by the atmospheric oxygen dissolved in the water; such dissolved oxygen being well known to be, chemically, much more active than the gaseous oxygen of the air. If, therefore, water contaminated with organic "matter be perfectly excluded from "the air in a carefully-stoppered bottle, "the gradual diminution in the amount "of dissolved oxygen indicates exactly "the process in the oxidation of the "organic matter."

This he proved by experiments. It is true that in a subsequent paragraph he states that "the experiments showed "that, in fact, no sewage whatever was so "converted or destroyed even after the "lapse of a week, since *the amount of "carbonic acid dissolved in the water "remained constant during the whole "period* of the experiment, whilst, if "the sewage had been converted into "inorganic compounds, the carbonic "acid, as one of these compounds, must "have increased in quantity."

The above experimental evidence is, in my opinion, contradictory. If oxygen disappeared as he proved it did, an equal volume of carbonic acid to that of the oxygen which disappeared must have been produced; hence, I am inclined to doubt the accuracy of his carbonic acid determination, and this the more that I have experimental proof that in sewage effluents the volume of carbonic acid produced represents the experimental volume of oxygen absorbed. Upon this he founded his conclusion that "it will be safe to infer, however, "from the above results, that there is "no river in the United Kingdom long "enough to effect the destruction of "sewage by oxidation."

Such a conclusion is opposed to the facts observed by all other investigators.

Oxidation of Organic Matter.

From the foregoing statements it is clear that the ultimate aim of true sewage purification consists in the oxidation of the organic matter, and it is to the study of these changes which sewage undergoes under such conditions that suitable chemical tests have been applied to measure such changes.

Nature of Organic Matter.

All organic matter contains carbon, but it may be wholly destitute of nitrogen. The organic matter of sewage, however, always contains organic nitrogen, although from the varying composition of sewage no constant or even approximate ratio of carbon to nitrogen can be assumed.

Chemical Analysis.

Chemical analysis is mainly concerned with the determination of the carbon and nitrogen in some form or other, and from the amount and condition of these two elements found the character of the organic matter may be judged.

Methods of Analysis.

The chemical processes employed may be divided under two general heads :—

1. Where the organic carbon and nitrogen are determined from the residue after evaporation of the water; and
2. Where the organic carbon and nitrogen are determined in the original water.

Under the first head the processes aim at the determination of the total organic carbon and nitrogen, and under the second head at the partial oxidation of the organic carbon and nitrogen.

Under the first head we have the ignition process, the Frankland combustion process, and other modifications, all based on the combustion of the residue left after evaporation.

Under the second head we have processes involving the use of oxidising substances such as chromic acid, permanganate of potash, &c.

In addition to these processes there are other processes for measuring the nitrogen compounds existing as ammonia (free and saline), nitrous acid, and nitric acid

In addition to these determinations, it is also necessary under certain circumstances to determine the dissolved oxygen and its rate of absorption, also the suspended solids, soluble solids, chlorine, transparency, and the physical properties of the effluent, such as colour, odour, &c.

I do not think that it is necessary at this stage to enter into the merits or the demerits of all the available tests which have been applied to the examination of sewage effluents. Suffice it to state that in my opinion purely chemical analysis is sufficient to afford a safe criterion as to the fitness of a sewage effluent to be discharged into a water-course.

The Main Tests relied upon.

The main tests to which I attach importance, and which are in daily use in my laboratory, are the following :—

Estimation of—

1. Free and Saline Ammonia.
2. Albuminoid Ammonia.
3. Oxygen absorbed from permanganate of potash in acid solution acting for 3 minutes at 60° Fahr.
4. Oxygen absorbed from permanganate of potash in acid solution acting for 4 hours at 60° Fahr.
5. Nitrites and Nitrates.
6. Incubator Test.

Interpretation of analytical results.

The results obtained from these tests do not express any fixed or definite ratio to the organic matter present, but have value as a means of comparing, or of tracing, the increase or decrease of impurities in various sewages and effluents of the same general character; and what they also do is to determine whether or not the effluents are liable to secondary decomposition, or cause pollution of the waters into which they may flow. Whilst supporting the methods which I have endeavoured to indicate as of value, I am far from wishing to disparage the processes that other chemists have devised and adopted, which may be in their hands, and in their opinion, of equal value—the object of all being to ascertain whether an effluent is fit or unfit to be passed into a stream. My experience, especially so far as regards the work in connection with the Mersey and Irwell Joint Committee, leads me to the opinion that what is required is not so particularly exact conformity of results in the analysis of sewage effluents, but correct interpretation of those results. The carrying out of any particular process is a comparatively simple thing compared with the interpretation of the results that follow, and it is here that the experience of the trained chemist is able to discriminate the true value of his analytical results, no matter by what reliable process they have been arrived at, and to draw such conclusions as the test or tests may bear chemically. Perhaps I may be allowed to illustrate my meaning by referring to a typical instance where in a very important trial it was contended that the per. manganate test was a fallacious test, because the sewage effluent contained ferrous iron which would affect the test. *Primâ facie* this would appear to be a good contention, but on consideration it is clear that any sewage effluent that would affect the oxygen absorbed test four hours to the extent of $\frac{1}{10}$th of a grain, oxygen absorbed per gallon would have to contain $\frac{1}{10}$ths grain metallic iron in the ferrous condition, and such an effluent I need hardly state is exceptional, and as a matter of fact has not been found by me in any sewage effluent, even when ferrous salts were used as a precipitant of the raw sewage. On the other hand, exceptional cases do arise where particular tests lose their value, and it will be necessary in the course of my evidence to refer to two special cases where the permanganate test alone cannot be relied upon as a measure of the sewage or organic pollution.

Moreover, it will be necessary to point out that certain chemists have attempted to show that particular methods of analysis of polluted water are wholly unsuitable by applying inappropriate tests. For instance, the albuminoid-ammonia test has been applied to the examination of a polluting liquid containing no organic matter that would yield albuminoid ammonia.

On the other hand, others have attempted to show that because the results, say, from the albuminoid-ammonia test do not agree with the results from the oxygen-absorbed permanganate test, either one or the other of these methods is faulty. They appear to believe that the results of any chemical test that deals with the oxidation of carbon ought to give comparable results with the results of a test applied to the oxidisation of nitrogen, and they overlook the fact which I have previously stated that there is no definite ratio between the organic carbon and nitrogen in the complex organic matter of sewage and of sewage effluents.

Definition of a Polluting Liquid.

The object of the chemical examination of a sewage effluent is to determine whether it is or is not a polluting liquid, and that I define as being a liquid containing organic matter, which, under suitable conditions, will undergo putrefaction. One test employed is to place a bottle, filled with the liquid and closed airtight, to a temperature of 75° Fahr. for 5–7 days. In many cases a liquid thus treated does not putrefy because the microbic life, necessary to produce putrefaction is not active. In all cases the incubator test must be strengthened and controlled by chemical analysis, viz., the determination of the free and albuminoid ammonias, and the oxygen absorbed from permanganate of potash, and if these are beyond a certain amount, I should certainly not pass the effluent.

How ascertained.

Limit to the Definition of a Polluting Liquid.

It must be distinctly understood that this definition of a polluting liquid does not apply either in the case of a sewage effluent flowing into a river the water of which is used for drinking purposes, nor to an effluent flowing directly into tidal waters.

In the case of effluents falling into rivers the water of which is used for potable purposes, a much stricter rule must be applied than is necessary on the Mersey and Irwell Watershed; and on the other hand, in case of an effluent flowing directly into tidal waters, less stringent rules than those applied in the Mersey and Irwell Watershed are necessary.

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Standards.

I have from the beginning of my experience in this subject, advocated the impossibility of fixing definite standards for sewage effluents, and to this I still adhere. It is true that I have proposed certain limits of impurity for the Mersey and Irwell Watershed, and these I shall explain hereafter. It is also true that I should insist on every effluent being brought within those limits, provided of course, that the application of the best practical and available means can be carried out so as to effect this. I may explain by reference to a special case why I take this view.

I will refer to the effluents from Manchester and Stretford. In both cases the effluents must be such that they do not undergo putrefaction, and we know that this can be accomplished, and I should be satisfied, in either case, to pass the effluent as good when it does not exceed the limits; but by the application of the best practicable means, it may be that Stretford (as is really the case) can do very much better than these limits require, whilst it is possible that Manchester may not be able to do so. It would obviously be absurd, therefore, to say to Stretford, "though when you carefully work you are so much below the limit, yet as those are our limits you may work carelessly," as it would be to say to Manchester, "because Stretford can always work below the limit we will insist on your doing so also, even though this cannot be obtained by the best practicable and available means."

I have convinced myself that by the application of the best practicable means at present known there is not a single effluent that cannot be brought down to the limits of impurity.

Limits of Impurity.

The limits of impurity which were suggested by me in November, 1894, are given in a report presented to the Mersey and Irwell Joint Committee, copy of which I hand in. These limits were only adopted for the purpose of criticising and comparing the results in these particular cases, and to classify the effluents.

The following are the limits of impurity fixed:—

1. Oxygen absorbed test. Permanganate of potash in acid solution. Four hours test made at 60° Fahr. One grain oxygen per gallon.
2. Ditto. Three minutes test. Quarter grain oxygen per gallon.
3. Albuminoid ammonia $\frac{1}{10}$ grain NH_3 per gallon.

Classification of Sewage Effluents.

If we review the results of analyses of sewage effluents made during the year, January to October inclusive, 1898, we find some interesting information.

The effluents are first classified according to the permanganate test.

TABLE 1.

PERMANGANATE TEST—FOUR HOURS. RESULTS OF THE EXAMINATION OF SEWAGE EFFLUENTS SUBMITTED BY THE MERSEY AND IRWELL JOINT COMMITTEE.

January to October, 1898. 10 months.

Effluents that absorbed oxygen from—

Class A.	0·07	up to	0·5	grain per gallon	93 Good effluents.
B.	0·5	grain to	1·0	" "	82 Fair effluents.
C.	1·0	"	1·25	" "	23 Doubtful effluents.
D.	1·25	"	2	" "	35 Unsatisfactory effluents.
E	2	" and upwards		" "	46 Bad effluents.

279 Tests.

	Effluents from		
	Raw Sewage.	Precipitation alone.	Filtration.
Class A	0	0	93
" B	0	1	81
" C	0	3	20
" D	0	5	30
" E	3	36	7
	3	45	231

Precipitation alone—

		Oxygen absorbed—Four Hours' Test.	Cases.
Class A.		None	0
" B.	Prestwich	1·00 grain per gallon	1
" C.	Rochdale	1·01, 1·05 "	3
	Whitefield	1·18 "	
			4

CLASS A. 93 Good Effluents.
All absorbed less than $\frac{1}{4}$ grain oxygen. Three minutes' test.

CLASS B. 82 Fair Effluents.
In 71 cases the oxygen absorbed was less than 0·25 grain oxygen. Three minutes test. In 11 cases the limit was exceeded. In 5 cases it only exceeded the limit by $\frac{1}{100}$th part of 1 grain, and in 2 cases by $\frac{1}{50}$ part of 1 grain.

TABLE 2.

CLASS B.
11 Effluents that exceeded the limit of $\frac{1}{4}$ grain oxygen absorbed. Three minutes' test.

	Three Minutes' Test.	Four Hours' Test.
Eccles	0·26	0·62
Crompton	0·26	0·95
Mottram	0·26	0·86
Worsley (Boothstown)	0·26	0·86
Marple	0·26	0·92
Marple	0·27	0·80
Atherton (Hindsford)	0·27	0·98
Timperley	0·30	0·66
Bowdon	0·32	0·75
Hale (Upper Outlet)	0·32	0·97
Westhoughton (Roger's Farm)	0·32	0·79

Class C. 23 Doubtful Effluents.
In 12 cases the limit of $\frac{1}{4}$ grain oxygen absorbed was exceeded.
In 11 cases the results were below the limit. (See Table 3.)

TABLE 3.

Authority.	Sewage Effluent from	Oxygen absorbed from KM_xO_4		Previous Samples Collected, January to October, 1898. Results of Permanganate test, 4 hours.
		3 min.	4 hours.	
Wardle	Artificial filtration	0·32	1·01	0·23, 0·44, 0·88
Prestwich	" "	0·33	1·02	
West Houghton (Roger's Farm)	Land	0·10	1·06	0·40, 0·92, 0·79
Norden	Artificial filtration	0·20	1·07	1·43, 1·55, 1·86, 2·87
Altrincham	Land	0·22	1·08	2·71, 0·36, 1·61, 1·63
Pendlebury	Artificial filtration	0·39	1·08	0·32, 0·63, 0·89
Withington	Land	0·26	1·10	0·45, 0·49, 1·10, 1·90, 1·30
Bowdon	"	0·22	1·10	0·71, 0·34, 0·80, 0·75
Mossley	Artificial filtration	0·10	1.11	0·33, 0·35
Offerton (Stockport)	" "	0·24	1·11	0·50, 0·53, 0·55, 0·60, 0·61, 0·64
Bury (Tottington)	Land	0·25	1·12	1·44, 0·50, 0·72
Northenden	"	0·12	1·15	0·39, 1·59, 0·94, 1·35
Heywood	Artificial filtration	0·36	1·16	
Atherton (Hindsford)	" "	0·23	1·16	0·98
Hale	Land	0·32	1·17	0·94, 0·94, 0·97
Little Hulton	Artificial filtration	0·38	1·18	0·41, 1·66
Moss Side	Land	0·81	1·19	
Wilmslow	"	0·34	1·23	0·45, 0·14, 0·26, 0·36, 0·59, 0·59, 0·73, 0·73, 0·22
Tyldesley	Artificial filtration	0·46	1·25	1·59, 1·71, 4·80
Astley Bridge	" "	0·29	1·25	0·24, 0·39, 1·50
Whitefield	Chemical precip'n	0·11	1·18	
Rochdale	" "	0·20	1·01	
Rochdale	" "	0·31	1·05	

With regard to these effluents it is to be observed that in many cases former samples have given superior results. For instance take the case of—

Wardle—Oxygen absorbed, 1·01.
Previous samples gave 0·23, 0·44, 0·88.
Bowdon—Oxygen absorbed, 1·10.
Previous samples gave 0·71, 0·34, 0·80, 0·75.
Offerton—Oxygen absorbed, 1·11.
Previous samples gave 0·50, 0·53, 0·55, 0·60, 0·61, 0·64.
Wilmslow—Oxygen absorbed, 1·23.
Previous samples gave 0·45, 0·14, 0·26, 0·36, 0·59, 0·59, 0·22, 0·73.

In cases where there is any great divergence from the general average result, it is advisable to call the attention of the Sanitary Authority to the result of analysis, and in a large number of cases the cause of the abnormal result has been traced, and in some instances remedied.

On the other hand, in some of these doubtful cases previous samples have been always unsatisfactory.

Take the case of Norden, where the artificial filters are admittedly too small.

Amongst the doubtful effluents is one where the oxygen absorbed was 1·07.

Previous samples gave 1·43, 1·55, 1·86, and 2·87.

or Tyldesley, where artificial filters are also admittedly too small, oxygen absorbed was 1·25.

Previous samples gave 1·59, 1·71, and 4·89.

CLASS D. 35 Unsatisfactory Effluents.
In 32 cases the limit of ¼ grain oxygen absorbed was exceeded.
In 3 cases the results were below the limit.
Hale 0·17 (land filtrate).
Hyde 0·16 (tank effluent).
Norden 0·24 (filtered effluent).
(*See* Tables 4 and 5.)

CLASS E. 46 Bad Effluents.
Of these 45 exceeded the limit of ¼ grain oxygen absorbed.
In 1 case the result was below the limit.
Hyde 0·22 (tank effluent).

With regard to the albuminoid ammonia results the limit of one-tenth grain per gallon has been exceeded in all the cases of unsatisfactory and bad effluents.

With effluents absorbing less than 1 grain oxygen per gallon, 4 hours' test, a few cases occur where the albuminoid ammonia result is higher than the limit. (See Table 8).

On the other hand, I have come across only two instances where in a sewage effluent the albuminoid ammonia has been less than one-tenth grain per gallon when the 4 hours' test was more than 1 grain, but these two cases are explicable.

The permanganate test has been disturbed only in two instances; that of Reddish, where the presence of carbolic acid gave an exceptional high result, and in the case of Manchester. (*See* Tables of Analyses and Diagrams.)

It is possible to find in a sewage effluent in which putrefaction has taken place that the amount of albuminoid ammonia is low compared with the amount of oxygen absorbed, but even in these exceptional cases the permanganate test (oxygen absorbed) indicates serious impurity, where the albuminoid ammonia may not do so.

The fact that a putrescent water does show excess of oxygen absorbed but a relatively small amount of albuminoid ammonia is well illustrated by the analyses of the Ship Canal Waters, copy of which I hand in.

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Take the average of eight analyses from six different points in the Canal:—

—	Oxygen absorbed.		Albuminoid NH_3
	3 minutes' test.	4 hours' test.	
No. 1	·44	1·25	0·082
„ 2	·50	1·54	0·082
„ 3	·47	1·31	0·090
„ 4	·50	1·39	0·104
„ 5	·44	1·18	0·080
„ 6	·59	1·43	0·085

The relation between the oxygen absorbed and the albuminoid ammonia is still more clearly shown in the following analyses, in which the change of relation of the two is clearer shown. Take the Manchester tank effluent analysed before and after incubation. (*See* Report, April, 1897.)

The average of 18 analyses gave 0·226 albuminoid before incubation, and 0·120 after incubation; whereas the 4 hours' test was 2·27 before incubation and 2·15 after incubation.

The 3 minutes' test was 0·67 before and 1·05 after. All the tank effluents became putrid in the incubator.

Another point of interest is the fact that the clear effluent becomes turbid and deposits solid matter on incubation, and it is this solid matter which contains organic matter capable of yielding albuminoid ammonia. Hence the necessity of analysing the liquid containing the suspended matter and not the clear liquid.

(See Table K for the result of these experiments. Also Table L.)

Analyses of Raw Sewage.

ANALYSES OF RAW SEWAGE.

Report to the Rivers Committee of the Manchester Corporation, dated September 7th, 1894, contains a series of analyses showing that the composition of the raw sewage varies very considerably. Thus, taking the total solids as a measure of the impurity, it is seen that the day sewage varies in total solids from 68·5 grains per gallon to 157 grains, the night sewage from 50 grains to 96 grains.

A more remarkable and regular difference is seen between the composition of the day and night sewage. The average composition of the total solids in twelve days' sewage was 96·8 grains per gallon, the corresponding figure for the night being 57·8. The total suspended matter in the day 40·5 grains per gallon, at night 15·4. The total organic matter in the day 34·1 grains per gallon, and at night 16·6.

To put it shortly, the day sewage is about twice as impure as the night.

Analyses of Tank Effluent, Cinder Filtrate, Coke Filtrate, & Land Filtrate.

ANALYSES OF TANK EFFLUENT, CINDER FILTRATE, COKE FILTRATE, AND LAND FILTRATE.

Report to the Rivers Committee of the Manchester Corporation, dated April 14th, 1896.

These analytical results show the percentage reduction of organic impurity as measured (1) albuminoid ammonia and (2) oxygen absorbed, 4 hours' test. Cinder filtration removed 54·6 per cent. of the organic impurity in the tank effluent, and the coke filter 52·3 per cent. as measured by the albuminoid ammonia test. The oxygen absorbed, 4 hours' test, showed a reduction of 57 per cent. in the case of the cinder filter, and of 49·4 per cent. in that of the coke filter.

Analytical figures are also given with reference to the liability of these effluents to putrefy.

Analyses of land effluents are also given.

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Still further analytical results are given in Report dated April 1st, 1897, in further continuation of the work done by filtration, and these results are of special interest, inasmuch as they indicate the natural improvement that was taking place in the action of the filters.

For instance, it will be observed that:—

1. The Free and Saline Ammonia was beginning to diminish in the filtered effluents.
2. The analytical results given by the filtered effluent from the first fill after the filters have rested, was, generally speaking, a little better than that from the third fill; and
3. The amount of Nitrates varied, the largest amount invariably being found after the first fill.
4. The percentage of organic impurity, as measured by the (1) albuminoid ammonia, (2) oxygen absorbed, four hours' test, and (3) oxygen absorbed, three minutes' test, taking the impurity in the tank effluent as 100, has been as follows:—

	Albuminoid Ammonia.	Oxygen absorbed. 4 hrs. test.	Oxygen absorbed. 3 mins. test.
Cinder filtration	70·5	65·8	62·6
Coke "	65·5	59·9	55·7

A summary of 18 analyses is given in Table M:—

TABLE M.

TABLE SHOWING COMPARISON OF RESULTS OBTAINED IN 1896 WITH THOSE OBTAINED IN 1897.

Period of Working.	Number of Days Working.	Volume of Tank effluent filtered, in Gallons.	Gallons per Square Yard per 24 hours.	Equivalent to Gallons per Acre per 24 hours.	Albuminoid Ammonias.			Oxygen absorbed—4 hours' test.			Oxygen absorbed—3 minutes' test.			Nitrogen as Nitrites and Nitrates.			Percentage reduction of Albuminoid Ammonias.		Percentage reduction of Oxygen absorbed—4 hours' test.		Percentage reduction of Oxygen absorbed—3 minutes' test.	
					Tank.	Cinder.	Coke.	Tank.	Cinder.	Coke.	Tank.	Cinder.	Coke.	Tank.	Cinder.	Coke.	Cinder.	Coke.	Cinder.	Coke.	Cinder.	Coke.
1896.																						
January 22nd to March 22nd	61	260,750	171	827,640	·240	·116	·120	1·87	·811	·955	·43	·25	·29	·109	·061	·069	54·6	52·3	57·0	49·4	41·8	32·5
March 9th to March 15th -	7	23,000	160	774,400	·158	·026	·035	1·47	·55	·64	·40	·19	·22	·123	·037	·044	83·5	77·7	62·5	56·4	52·5	45·0
1897.																						
March 8th to March 14th -	7	* 31,500	* 180	* 871,200	·226	·067	·079	2·27	·81	·92	·67	·25	·30	·137	·199	·129	70·5	65·5	65·8	59·9	62·6	55·7

* Correcting these figures for loss of water capacity of filters (*see* Report dated 18th June 1897) the following figures are obtained:—

—	Volume of Tank effluent filtered, in Gallons.	Gallons per Square Yard per 24 hours.	Equivalent to Gallons per Acre per 24 hours.
Cinder Filter -	26,586	152	735,680
Coke Filter -	24,840	142	687,280

	Record of Time in Working Filters.				
	Filling.	Resting full.	Emptying.	Aerating.	Total hours.
1896, January 22nd to March 22nd.	10·2	20·5	10·2	59·1	100
1896, March 9th to March 15th.	9·5	20·2	9·5	60·8	100
1897, March 8th to March 14th.	5·35	21·4	5·35	67·9	100

Frank Scudder,
For Sir *Henry Roscoe.*
April 1st, 1897.

Durability of Artificial Filters.

REPORT ON THE CAPACITY OF THE EXPERIMENTAL FILTER BEDS AT DAVYHULME SEWAGE WORKS.

June 18th, 1897.

On December 16th, 1895, the cinder and coke filters were put into operation. On December 18th, 1895, the capacity of the coke filter was determined and found to be between 1,720 gallons and 1,760 gallons, and for the purposes of calculation the capacity of both filters was taken at 1,750 gallons each. This figure was adopted throughout all my reports, including the Report dated April 1st, 1897.

On March 23rd, 1896, both filters were carefully measured and were found to contain—

Cinder filter, 1,663 gallons.
Coke filter, 1,709 ,,

On May 27th, 1897, both filters were carefully measured under the same conditions as on March 23rd, 1896, and were found to contain—

Cinder filter, 1,477 gallons.
Coke filter, 1,380 ,,

That is, after 14 months' working, the cinder filter had lost 11·2 per cent. of its water capacity, and the coke filter 19·25 per cent.

The cinder filter on May 27th, 1897, was swollen, the top being spongy, soft, and clean. It took 84 gallons more than the 1,477 gallons to fill the filter so as to submerge all the cinders, the tank effluent carrier being below the top of the cinders.

The coke filter had, however, sunk deeper, and was covered with caked solid matter, which had curled up in patches with the heat of the sun.

Correcting the figures given in my report for April 1st, 1897, for the loss of water capacity, it is seen that instead of the volume of tank effluent filtered being 31,500 gallons for each filter per week, the volume for the cinder filter is 26,586 gallons, and for the coke filter 24,840 gallons. In other words, on March 23rd, 1896, the filters were working at the rate of 171 gallons per square yard per 24 hours, in the case of the cinder filter, and at the rate of 175¼ gallons in that of the coke filter, whereas on May 27th, 1897, the rate of filtration in that of the cinder filter was 152 gallons per square yard per 24 hours, and in that of the coke filter only 142 gallons.

The coke filter has lost in water capacity nearly 100 per cent. more than the cinder filter, and it is therefore obvious that the loss of water capacity is not entirely due to subsidence of foreign matters within the filter itself. Moreover, on March 5th, 1897, the coke filter was particularly tested to see whether any suspended solids could be washed out, and in my

Report dated April 1st, 1897, I reported as follows: "In order to more severely "test the coke filter, a rapid flow of "tank effluent was passed through "the filter for about half an hour, "and it was observed that the filter "was capable, even under these con- "ditions, of effecting clarification, *no "suspended matters being washed out "into the filtrate* by the high rate of "filtration."

Nothing less than absolute control of the filters for a time in order to study the functions of the filters would enable any correct deductions to be drawn as to the cause of the loss of water capacity. Possibly, as I have previously suggested (*see* Report, April 14th 1896), a modification of the method of working the filters would bring about more permanent and satisfactory results.

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The question of the lasting power of the filter is important, and my experience on this point is that the material does undergo a change, and that the quantity of liquid that could be passed through does diminish in the course of time. How long it will take to become inefficient time alone can show. We have not yet had sufficient experience, and upon the cost of working the artificial process largely depends.

3511. I would next ask you if you could describe to us shortly the best practicable means that you would propose to adopt for sewage treatment?—Yes. Perhaps it would be well for me to put shortly a general statement with regard to the question of sewage pollution. In the first place, then, I assume that raw sewage cannot be allowed to flow into the rivers—as it is a polluting liquid; in the second place, that the effluent from any available chemical treatment is also unfit, and is a polluting liquid, inasmuch as the effluent is charged with a large proportion of soluble putrescible matters; thirdly, that, either by land filtration or artificial filtration, with or without previous treatment, an effluent can be obtained which can be allowed to pass into the stream, and is not a polluting liquid. The question, therefore, to be considered is what system or systems of filtration are to be adopted. The two main methods in use are, first, land filtration, including broad filtration (sewage farms) and in the second place, artificial filtration. With regard to the first method, there is no doubt that, where the conditions are suitable and where the process is efficiently carried out, the results are satisfactory. I may say that on the Mersey and Irwell watershed we have evidence of this. I may mention the two cases of Wilmslow and Altrincham, where a good effluent has been obtained. (See Table 3, page 204.) In the report which was presented to the Rivers Committee of the Manchester Corporation on the chemical analyses of tank effluent, cinder filtrate, and coke filtrate, you will find the effect of the filtration on the tank effluent after precipitation. These are not only, you will find, numbers giving the results of analyses, but also what I venture to think is a very useful method of bringing the subject home to one's mind, a series of diagrams showing the results diagrammatically of the analyses. Of course, if it is desirable, I could go into the full details of these, but, perhaps, if they are placed before the Commission that may suffice. With regard, then, to the land filtration, it is unfortunate that land of a suitable character and area necessary in order to effect what I say can be brought about, and is brought about in certain places, namely, a satisfactory effluent, especially in the case of large towns, is difficult to acquire, and where possible in many cases the cost is often excessive, and therefore in many instances artificial filtration has to be resorted to. With regard to the different proposed methods of artificial filtration as distinct from mere mechanical filtration, all more or less depend upon the purifying action of bacteria, and by the adoption of such means it has been abundantly shown that satisfactory results are obtainable. I have myself shown, by a long series of experiments carried out with Manchester sewage, that artificial filtration can be applied with success to an effluent containing both sewage and manufacturing refuse of all kinds, and varying in its composition even from hour to hour. In proof of this I beg to submit the reports to which I have already referred, and also a table, which I hand in, showing that out of 119 tests on the sewage effluent from 41 sanitary authorities resulting from artificial filtration, 88 were of a satisfactory character.

LAND FILTRATION.

112 Tests made from 38 Sanitary Authorities, January to October, 1898. Effluents that absorbed oxygen 4 hours' test from—

0·07 up to 1 gr. per gal.	86
1 gr. to 1·25 „ „	8
1·25 gr. to 1·5 „ „	7
1·5 and upwards - -	11
	112 tests.

ARTIFICIAL FILTRATION.

119 Tests made from 41 Sanitary Authorities, January to October, 1898. Effluents that absorbed oxygen 4 hours' test from—

0·07 up to 1 gr. per gal.	88
1 gr. to 1·25 „ „	8
1·25 gr. to 1·5 „ „	9
1·5 and upwards - -	14
	119 tests.

3512. On that might I just ask you when you say you have got good effluent from your land treatment, is the effluent good all the year round?—Yes, so far as we are able to trace it, the effluent is good all the year round. The question did arise as to whether the winter temperatures would be inimical to the action of the purifying agent, but I think the evidence, so far as I have been able to obtain it, shows that the winter temperature does not interfere materially.

3513. And when the land is frozen, does it do any harm?—Well, I have not had cases where the land was frozen.

3514. You have not tried it?—No, but even then I think that in large towns, at any rate, the temperature of the sewage will always be above the freezing point—I mean, sufficiently above the freezing point to enable the purifying action to go on. If we take Manchester, for example, where there are something like 26,000,000 gallons coming down daily, the temperature of that liquid is always sufficiently high to enable the purifying action to take place.

3515. But would it not flow over the surface of the frozen land, instead of flowing through it?—Oh, in cases of land filtration there would no doubt be a difficulty.

3516. (*Sir Richard Thorne.*) May I ask you one question, Sir Henry Roscoe, on that last sentence of yours, namely, that out of 119 tests 88 were satisfactory?—Yes.

3517. Does that mean 119 solitary tests, or were they sewage effluents that were discharged at different times according to differing rainfall, temperature, etc.?—The latter.

3518. Then you say, of sewage effluents resulting from artificial filtration 88 were of a satisfactory character. You have just said that artificial filtration without previous treatment will suffice. Were those 88 without any previous treatment all the result of simple artificial filtration?—No, I think that in many cases there was also precipitation.

3519. Then it is artificial filtration plus precipitation?—Plus precipitation.

3520. Plus previous treatment?—Plus previous treatment.

3521. Yes, that alters the case a good deal?—In referring to this question of artificial filtration, might I refer to the former page, namely, on page 15, in which I have described the action of the experiments of filters which under my charge were working for some time at Davyhulme for the Corporation of Manchester. I say, at the top of page 309 the question of the lasting power of the filter is important, and my experience on this point is that the material does undergo a change, and that the quantity of liquid that could be passed through does diminish in the course of time. How long it will take to become inefficient time alone can show. We have not yet had sufficient experience, and upon the cost of working, the artificial process largely depends. I should like to add that, since I wrote this, I have received the evidence which was given before a Local Government Board inquiry only last week.

3522. (*Chairman.*) A Local Government Board inquiry where?—A Local Government Board inquiry which has been made in Manchester on an application to the Local

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Government Board for sanction to borrow money for purposes of sewerage and sewage disposal, before Major-General H. D. Crozier, R.E., and Theodore Thompson, Esq., M.D., because in this evidence reference is made to the question of the capacity and of the filtering power of these particular filters, which I started some three years ago, and which has been carried on by a chemist under the direction of the Manchester Corporation. I think it might be important to hand in a drawing of these filters, as they are the ones that I rely upon most in my evidence. (*Drawing put in.*) And I think, perhaps, I might bring before you the answers which were given on this occasion last week on this subject, because it shows that since I reported to the Corporation those filters have been in continuous work, and at the present time are doing their work admirably well. The question 469 is by Mr. Balfour Browne.

3523. (*Professor Foster.*) May I ask a question, my Lord? Are these the two small experimental filters that we saw the day we were there?—Yes, they are.

3524. I think as we were walking towards the outfall?—Yes, those are the two. The questions were put by Mr. Balfour Browne, who appeared for the Manchester Corporation, and he asks the questions of Mr. Gilbert J. Fowler, who is the resident chemist:—"I want to ask you about another matter before we come to some of your tests. It is the question of the loss of capacity of the filters by user. You have had an experience of two and a-half years of the working. Will you tell us, especially in the case of the Roscoe filters"—(I do not like the use of my name in that sort of way)—"or Roscoe beds, what you have to say with regard to the loss of capacity?—Our experience with regard to the loss of capacity has been that the loss was very considerable in the first few months of working. If we take the measurements from December 19th, 1895—which were made, I believe, by Mr. Scudder—down to those made on April 26th, 1897, there is a total decrease of something like 20 per cent.; but if we go on from that time until the present time"—(that, you see, is about a period of two years)—"until the present time, we find that the total decrease in capacity—taking an average, and taking the measurements under the same conditions, which is most important—the total decrease amounts to only about two or three per cent. (*Q.*) Then you think, after working a certain time, you get practically a stable condition, or nearly a stable condition, so far as capacity is concerned?—(*A.*) It seems to be so. We have noticed that, while the filters have ceased to lose capacity, the surface has to some extent been raised. That is to say, it looks as if a good deal of the suspended matter accumulated on the surface, and the surface, from being rough gravel, has come to be more in the condition of fine soil. At the same time, with that change in the character of the surface the efficiency—the chemical and bacteriological efficiency—of the filters appears to increase. (*Q.*) I was going to ask that question?—(*A.*) So that during the last year our results have undoubtedly been chemically more satisfactory than in previous years. (*Q.*) Therefore, this loss of capacity is not an injury really to the contact power of the filter, but rather increase it?—(*A.*) That appears to be the case; and I may say, further, that recently we have tried experiments of putting more effluent upon these filters—that is to say, instead of filling them three times, we fill them four times a day. That makes the quantity we are dealing with now up to the original quantity dealt with on the 16th December, 1895. We have had this going for a month now, and the results have been uniformly satisfactory."

3525. (*Sir Richard Thorne.*) May I just ask if that refers to artificial filtration alone or artificial filtration following some chemical treatment?—Artificial filtration, following the precipitation treatment.

3526. Then it is impossible to judge of the value of the filtration process without knowing what the precipitation process was, and what it did?—I know what it was, and I know what it did.

3527. I mean we could not judge?—No, you would have to know what the previous chemical treatment was, of course.

3528. (*Mr. Killick.*) I might say, my Lord, the Town Clerk of Manchester has promised to give us full notes of this inquiry, and therefore this will all be put in.

3529. (*Sir Richard Thorne.*) But that ambiguity to my mind runs through a large portion of the evidence you have been good enough to lay before us. For example, in table 3 on page 306 we get artificial filtration, we get land, and we get chemical precipitation?—That is so.

3530. Now as to artificial filtration in all these cases; are we to judge of it in contrast to land treatment and to chemical precipitation, or do two processes sometimes go hand in hand?—In most cases the two go hand in hand.

3531. Then it is not really artificial filtration at Tyldesley and Rochdale as contrasted with chemical precipitation at Wilmslow and Rochdale?—No, as a rule, artificial filtration is subsequent.

3532. Then what we really have to compare in this evidence is in the main artificial filtration following on chemical precipitation with the other processes?—With chemical precipitation alone.

3533. Perhaps in looking through the evidence you will make that clear?—I will.

3534. It does not appear clear on the evidence?—Yes, I will take care to make that clear.*

3535. And the ambiguity runs right through the evidence?—I may add that, as I have said before, all these artificial filters presupposes chemical treatment. If that is not made clear, it should be made clear.

3536. I will explain to you why it is not quite clear, because one of your conclusions this morning is to this effect, that, amongst the best practical means, you had either land filtration or artificial filtration, in each case with or without previous treatment?—Yes, that is so.

3537. Therefore it does not quite follow that two linked processes are always in question?—I would say that in almost all the cases that I have reported upon, artificial filtration is accompanied previously by some method either of sedimentation or of chemical precipitation.

3538. That makes it clear, I think?—Yes. I think, perhaps, I might add—I am not sure whether I have made it quite clear—that I have no evidence to bring forward to show that raw sewage can be treated by artificial filtration alone. With land filtration the thing is different.

3539. Then may I ask the meaning of that conclusion which I have just read, that it can be done either by land filtration or by artificial filtration, with or without previous treatment?—Yes. I am much obliged, I shall be glad to explain that. I know that there are statements made that, without previous treatment, artificial filtration is possible. I did not in my evidence give any particulars because it has not come before me, and I only wish to say there that it is stated, but I do not propose, and I cannot enter into the question, but I only wish that to be noticed that it is stated that artificial filtration without previous treatment is a possibility.

3540. I notice now that it is below, and not above, your signature?—Yes.

3541. (*Colonel Harding.*) I want to ask Sir Henry a question on the important point that he has mentioned as to there being only three per cent. loss of capacity over a long period in the experimental filters at Manchester. I should like to know if he can tell us how many grains of suspended matter there were in the effluent that he is treating there?—You mean, in the effluent. Yes; well, I have not got that; perhaps Mr. Scudder will find that. The quantity does never exceed one and a-half grains per gallon.

3542. Is that in what flows from the filter—filtrate?—In what flows from the tanks on to the filters.

3543. Substantially, then, there was no suspended matter going to the filter?—Practically little suspended matter in the tank effluent.

3544. (*Chairman.*) May I ask you this, what importance you attach to the presence of nitrites and nitrates in the sewage effluent?—Nitrogen as nitrites and nitrates is not always present in filtered effluents, and when present, as a rule, only in very small amount, except where the filter has been aerated for some time, and the first waters do then invariably show a high nitrate result, and it is for those reasons the importance of this determination appears only to show that a certain amount of oxidation of organic nitrogen has taken place, but not necessarily that the whole has been oxidised. Analytical determinations have been made as to the amount of nitrates found in the tank effluents, and the filtered effluents in the Davyhulme samples, and I may refer to these as illustrating my view. Also to tables 7, 8, and 9, where various sewage effluents have been specially examined for nitrates.

* Thirty-eight Sanitary Authorities are using land filtration. Of these 16 adopted broad irrigation pure and simple: 13 sedimentation in tanks, but no chemicals, with subsequent land filtration; 9 precipitation by chemicals, settlement in tanks, and subsequent land filtration. Forty-one Sanitary Authorities are using artificial filtration. In all these cases chemical precipitation, with subsequent settlement in tanks, is used prior to filtration through filtering medium (See table on page 207.)

TABLE 7.

ANALYSES OF SAMPLES OF SEWAGE EFFLUENTS FROM NINETEEN SANITARY AUTHORITIES.

RESULTS EXPRESSED IN GRAINS PER GALLON.

Authority.	Oxygen Absorbed 4 hours.	Ammonias.		Nitrites and Nitrates as (N).	Nitrites.	Chlorine.	Remarks.
		Free.	Alb.				
Eccles	0·50	0·36	0·018	0·152	Distinct	5·1	Clear and colourless, free from smell.
Wilmslow	0·35	0·19	0·020	0·042	Faint traces	2·8	Clear and colourless, no smell.
Stretford	0·30	0·129	0·022	0·310	Abundant	6·0	Clear and colourless, free from smell, small quantity brown sediment.
Wardle	0·36	0·44	0·040	0·271	Slight traces	3·5	Clear, sparkling, free from smell.
Worsley (Barton Moss)	0·83	0·395	0·041	0·117	Distinct	4·6	Clear and colourless, no smell.
Altrincham	0·69	0·28	0·042	0·133	None	5·9	A slightly brown-coloured effluent, no suspended matter, no smell.
Westhoughton (Dog Holes Farm).	0·11	0·046	0·045	0·195	Trace	–	Clear and colourless, no smell
Littleborough	0·07	0·42	0·060	0·098	None	2·2	Clear and colourless, no smell.
Ashton-on-Mersey	0·56	0·70	0·055	0·006	None	3·5	Clear and colourless, free from smell.
Crompton	0·15	0·11	0·060	0·198	None	2·8	Clear, sparkling, no smell.
Withington	0·62	1·37	0·064	0·006	Faint trace	4·0	Colourless and free from smell, small quantity of brown suspended matter.
Westhoughton (Marsh Brook)	0·24	0·21	0·067	0·036	Trace	–	Clear and colourless, no smell.
Little Hulton	0·36	0·31	0·074	0·032	None	3·0	Clear and colourless, no smell.
Northenden (Bucklow R.D.C.)	0·42	0·61	0·084	0·057	None	3·4	Clear and colourless, with small quantity of white sediment, very faint smell.
Barton (Clifton)	0·28	0·43	0·090	0·700	Traces	5·1	Clear and colourless, free from smell.
Hale (Bucklow)	0·60	0·56	0·090	0·018	Distinct	3·7	Clear and colourless, free from smell.
Astley Bridge	0·85	0·92	0·098	0·252	Abundant	3·8	Clear and colourless, no smell.
Alderley	0·41	0·43	0·100	0·078	Distinct	4·0	Clear and colourless, no smell.
Hindley	1·07	0·175	0·105	0·047	Slight traces	3·0	A colourless effluent, with a little flocculent suspended matter, no smell.

TABLE 8.

ANALYSES OF SAMPLES OF SEWAGE EFFLUENTS FROM EIGHT SANITARY AUTHORITIES.

RESULTS EXPRESSED IN GRAINS PER GALLON.

Authority	Oxygen Absorbed 4 hours.	Ammonias.		Nitrites and Nitrates as (N).	Nitrities.	Chlorine.	REMARKS.
		Free.	Alb.				
Bury R.D.C. (Tottington)	0·30	0·61	0·11	0·18	Trace.	–	Clear, with just a little brown matter in suspension, no smell.
Worsley (Boothstown)	0·98	0·22	0·11	0·075	Strong traces.	2·7	A slightly brown coloured effluent, no smell.
Timperley (Bucklow R.D.C.)	0·64	0·32	0·12	0·03	Abundant.	3·8	Clear, colourless, free from smell.
Westhoughton (Roger's Farm)	0·65	0·80	0·13	0·049	Faint traces.	–	Clear, colourless, free from smell.
Turton	0·61	1·26	0·14	0·047	Abundant.	4·4	Clear, colourless, free from smell
Bowdon	0·47	0·48	0·18	0·133	Faint traces.	3·1	Slightly turbid, little flocculent sediment, no smell.
Marple	0·60	1·62	0·21	None.	None.	–	Slightly brown coloured, with little brown suspended matter, no smell.
Dunham Massey (Bucklow R.D.C.)	0·91	1·16	0·22	0·174	Plentiful.	3·0	Clear, with little grey sediment, no smell.

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TABLE 9.

ANALYSES OF SAMPLES OF SEWAGE EFFLUENTS FROM SIX SANITARY AUTHORITIES.

RESULTS EXPRESSED IN GRAINS PER GALLON.

Authority.	Oxygen Absorbed 4 hours.	Ammonias.		Nitrites and Nitrates as (N).	Nitrities.	Chlorine.	Remarks.
		Free.	Alb.				
Offerton (Stockport) - -	1·19	0·45	0·18	0·189	None.	–	Slightly pink coloured, some suspended matter, no smell.
Bowdon - - - - -	1·25	1·01	0·22	0·018	Strong traces.	3·4	A small amount of dark-coloured suspended matter, slight smell.
Dunham Massey - - -	2·24	1·00	0·24	0·002	None.	2·1	A dark-coloured effluent, having some black suspended matter, and a slight smell.
Knutsford - - - - -	1·83	3·16	0·39	0·022	Trace.	7·0	Slightly turbid, a little flocculent suspended matter, slight and putrescent smell.
Bollington - - - - -	2·33	1·87	0·47	None.	None.	6·0	Slightly turbid, with a quantity of white suspended matter, and faint putrescent smell.
Sale - - - - - -	3·94	1·66	0·87	—	Plentiful.	6·5	Turbid, with a quantity of black suspended matter and sewage fungus, and having putrescent smell.

3545. Could you say generally whether you prefer land or artificial filtration?—This seems to me to depend entirely upon the circumstances of the case, and I should doubt whether it would be possible—at any rate, I could not undertake to do so, to lay down any general principles upon this point. What I do say is this, that with suitable land and a limited quantity of sewage effluent, say a maximum of 60,000 gallons per acre—for in both cases I am supposing, as I told Sir Richard Thorne just now—the preliminary settlement by chemical treatment in tanks has been adopted, land filtration can be excellent; but where large quantities of sewage have to be treated, and where the necessary area of land is either insufficient or unsuitable, there artificial filtration at a maximum rate of 800,000 gallons per acre can with success be resorted to, because the area needed is very much less than is required for land filtration to obtain a good result. In support of these conclusions I refer you to the details of the reports which I have handed in.

3546. Following up Sir Richard Thorne's questions, do I understand that your experience is generally both with land filtration and artificial filtration that there is precipitation precedent to both of them?—Yes; that is to say, I have not had sufficient evidence put before me to enable me to state whether it is possible to put crude sewage containing solid matters on to an artificial filter with success.

3547. You have had experience, I suppose, of crude sewage going on to land without any precipitation?—Yes, in some few instances those that I refer to at Wilmslow and Altrincham.

3548. And could you tell us whether you have any opinion as to whether precipitation is desirable where it is a question of land filtration?—I think it all depends upon the conditions of the case. I think that if the quantity of the sewage is moderate and if the area of available and suitable land is satisfactory, then I believe that it may be done.

3549. Without precipitation?—Yes, but I think that those conditions are essential, and I also think that in most cases and in the important cases—I refer to large cities—that these conditions cannot be complied with.

3550. Then you would consider that in the case of a large city which dealt with its sewage by land treatment precipitation would most likely be necessary?—Yes, I do; I think it will greatly assist the action of the land filtration.

3551. And I believe that experiments are being conducted under your directions at Huddersfield and Pendlebury?—Yes.

3552. With a view to seeing whether crude sewage can go on to an artificial filter?—On to an artificial filter, yes.

3553. Without previous precipitation?—I am making experiments upon that subject, but I do not think they are sufficiently advanced to enable me to report in a way I should wish to do. Perhaps on some future occasion if you desire to have evidence on that point, I shall be able to bring it before you.

3554. (*Mr. Killick.*) There is one question I should like to ask which I think has been an omission in Sir Henry Roscoe's evidence. You have not stated, Sir Henry, the method upon which you have dealt or advised the Mersey and Irwell Committee to deal with manufacturers' effluents in the watershed?—I am much obliged to you, Mr. Killick, for asking me that question. The subject of the manufacturers' refuse is a totally distinct one, of course, from that of the sewage effluents. When I was first asked to assist the Mersey and Irwell Committee with regard to the purification of the streams, from refuse from manufacturers, in the first place I advised them that it would be absolutely necessary that the manufacturers should be treated with great consideration, and that we should endeavour to obtain their sanction and their good will, and that I may say we have succeeded beyond my expectation at the time in so doing, that is to say, that, with very few exceptions, the manufacturers have come forward and met the requirements of the Committee with results that have been altogether quite satisfactory. And as a proof of that I may say that we have now succeeded in entirely stopping what is after all the most important question as regards manufacturing effluents, that is the entrance of all solid matters into the rivers, so that at the present moment we may say that that is *un fait accompli*. In order to give an idea of the way in which the manufacturers have met us, I may say that a very considerable number of manufacturers on the streams, of which there are, as you probably know, several hundred, all differing in the amount of pollution—I say that many of those have spent many thousands of pounds in coming to an agreement with the Committee and putting up works. I may mention, for example, one particular case, at Dinting, near Glossop, the large calico print works of Messrs. Edmund Potter and Company, where they have spent something like £4,000 or £5,000. A similar works up on the other side in the valley has spent in the same way, so that I think that we have met with entire good will on the part of the manufacturers, and they have done what they could to improve the condition of the streams. That this improvement has been of importance, I may state that on some of the lower portions of the stream the water used to be extremely bad, so much so that the manufacturers were unable to use the water, one particular manufacturer was unable to carry on his works at all, and since our Committee has been at work the quality of the effluent has been so much improved that that which took them many days to accomplish can now be worked in as many hours, so that there has been a very considerable improvement in the condition of the streams in this respect. We have had a few cases in which manufacturers have been brought up before the Committee, and in which proceedings have been taken against them. In all those cases

—they have not been very numerous—the Committee have gained their case. There are some one or two of these various trades that are carried on in Lancashire which are difficult; otherwise I think on the whole the matter of helping the manufacturers to purify their effluent is not a very difficult one. In some instances we have been obliged to ask the Corporations to take in the drainage from these works from some tanneries and breweries situated in the town. Thus an arrangement has been made by which the manufacturing refuse which formerly went into the streams now goes into the city drains, and comes out and is treated along with the sewage, and that has been satisfactory. In other cases—there are certain few processes which are certainly very difficult to treat; for instance, the fellmongers, the treatment of skins, where they clean the skins the refuse and effluent is extremely bad, and it is necessary to do something more than to get rid of the solid constituents, but I may mention that in getting rid of the solid constituents in many cases a considerable quantity of the soluble noxious ingredients are also deposited, so that whilst we secure the complete absence of solid matter in the streams, we do, by that very process, get rid in a great number of instances of a very considerable quantity of the soluble impurities. In the case of these fellmongers the difficulty is great, but they are a small number, and they do not produce any very serious defect. I suppose the Commission will be well aware that although it no doubt is important that the manufacturing refuse should be dealt with, the far greater evil is that due to sewage from large towns, and there, as I at once informed the Irwell Committee, it is not a matter which requires any great amount of prevision, there is the difficulty. The difficulty in dealing with the manufacturers is comparatively small compared with the difficulty of dealing with these large manufacturing towns which drain and have drained ever since they existed into these streams, and in that respect, although progress has been made, yet one must confess that still a good deal remains to be done, and that the rivers would be in a very much better condition if all the authorities, especially the large ones on the streams, were doing what I think they ought to do.

3555. Might I ask Sir Henry to put this into figures: As regards manufacturers' effluents so far, under your advice, the Mersey and Irwell have only dealt with solids in suspension?—Yes, that is so.

3556. And you advised them that a good effluent is when there are no solids in suspension and where the solids in solution of an organic character do not exceed 12 grains to the gallon?—That is so.

3557. And the samples did not deposit any solid matter on standing two or three days?—Yes, that is so.

3558. You further advised us that an effluent with five grains or more in suspension is a bad effluent?—Yes.

3559. Inorganic solids in solution have not yet been dealt with?—No. As I said before, in the process of getting rid of the solids we get rid of a good deal of the soluble organic matter. I do not know whether I made that clear that in many of the cases of the manufacturers a system of filtration as well as of subsidence has been adopted.

3560. (*Professor Ramsay.*) You use the expression, Sir Henry, in your evidence in chief, "A polluting liquid"; would you in the light of your later explanation say that as a rule manufacturers' effluents are not "polluting liquids." At all events, if they are polluting liquids they can easily be dealt with?—Yes, I refer there to sewage alone. A polluting liquid in the case of a manufacturer would be a liquid containing solid material as well.

3561. Then you regard as by no means the most troublesome part of the problem the disposal of manufacturers' refuse?—No, I regard that as a much easier problem, and much more readily solved than that of dealing with the sewage.

3562. Then would you recommend that the effluents should be allowed to run into the rivers after their own purification, or that they should be united with the sewage before purification?—Well, it depends, as I have said, entirely upon the position of the manufacturer. If he is up in the country, as is the case in many of those works on our rivers, then there, of course, he has to run into the river. In the case of where he is situated within the area of a city having a system of drainage, there, of course, if the Corporation agree to it, he can send his sewage into the drains. But in every case, what I have leant upon is the clause which is so useful, because it is so elastic, namely, "the best practicable means"; that is to say, that, as regards the manufacturers, I have always avoided setting up a special standard, and I have always said that the object we have in view is to find out what are the "best practicable means" for dealing with this man's effluent. Indeed, the same thing applies to sewage effluents, as I have pointed out.

3563. Then I should like to ask some questions as to your tests for the polluting liquid?—Yes.

3564. Might I just follow the evidence as it runs? Beginning on page 299, you first allude to the self-purification of rivers. I suppose you regard it as certain that rivers will purify themselves?—Yes, I do. That is to say, within certain limits. I do not believe that our rivers in Lancashire would ever purify themselves completely before they got to the sea, but if you were to allow them to put a sufficient quantity of water in, and a sufficient quantity of the disturbing matter out, and have them of sufficient length, then self-purification might and would occur.

3565. Then that is obviously due to the absorption of oxygen, and you point out at the foot of page 4 that Sir Edward Frankland directed attention to that?—Yes.

3566. But now one would regard it, not as the absorption of dissolved oxygen, but the utilisation of that oxygen by bacteria?—Yes, that is so.

3567. Then as regards the nature of the organic matter, you attempt to determine that nature by various tests; one, for example, is the oxygen absorbed?—Yes.

3568. I notice that Mr. Dibdin in his evidence employs a different test from the one which is employed by Mr. Scudder. Mr. Dibdin tries the amount of permanganate which is used at once, and also after four hours, at 80° Fahr.?—Yes.

3569. Whereas Mr. Scudder estimates the permanganate which is destroyed after three minutes and after four hours at 60° Fahr.?—Yes, at 60° Fahr.

3570. Have any comparative experiments been made so as to bring those two methods into line?—I do not think that there is any very great discrepancy in this matter. I have in my hand the results of a series of experiments to ascertain if the difference between the four hours' test at the atmospheric temperature and at the incubation temperature makes appreciable differences in the results. Those done at the incubator were quickly raised to 78° Fahr. in a water bath, and then at once put into the incubator, and this shows that, as a result, the amount of oxygen absorbed in the four hours' test at the atmospheric temperature on an average was 0·62, whilst that at the temperature of the incubator at 78° was 0·85, so that there was rather more at the higher temperature than at the lower. All I should say with regard to these variations in the methods which have been employed is this, that I look upon the question in this light, that many chemists employ different methods, more or less different—chiefly less different—and that these differences of method do not affect the result as a whole. That is to say, supposing that Mr. Dibdin, whom you have quoted, has a sample sent to him to ascertain whether that is a polluting liquid; and the same sample is sent to myself, to Mr. Scudder, or to anybody else, we may apply somewhere different methods in order to ascertain that fact, but, as a rule, our results will agree. Either they will acquit the liquid as being a good one, or they will condemn it as being a polluting liquid. I may say that, in addition to what I have remarked, these experiments proved that the results obtained at a higher temperature, namely, at 75° or 80° Fahr., are more erratic—that is to say, that we find that the results at 60° are, taking one sample and analysing it several times, we find that the results obtained at 60° are, as a rule, more comparable or give more agreeing results than when you raise the temperature more. If the temperature be raised to a higher point, namely to 100°—I believe that has been proposed by some chemists—then the alteration becomes so great that no reliable results can be obtained. Might I say, in corroboration, or in continuation of this subject, I have made a note here which I think bears upon what you were asking me. The question you have raised is whether the different methods employed by different chemists give the same result.

3571. Whether we can standardise; whether we have got any common ground to go upon as regards comparison of different sewages?—I think, on the whole, that now chemists are pretty well agreed. Of course, you are well aware that Sir Edward Frankland proposed a method many years ago, which is known as Frankland's method, of determining what he calls organic nitrogen and organic carbon. Well, I am prepared to say that the method which he adopted, though it is very different from that

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which is adopted generally now, is capable of interpretation in the same way; that is to say, that if you adopted Frankland's method, or adopted the method which I have described, you still would arrive at the same result—you would say that this was a polluting liquid, or you would acquit it as not being one.

3572. But in comparing results with oxygen absorbed, as it is called, from different districts, say from the Mersey and Irwell, and from the Leeds district, or from Mr. Dibdin's filters, the difficulty is to compare the figures; they do not express the same thing?—Well, they express the same thing, so far as the question is merely to ascertain whether or not the liquid is a polluting one. The whole object that we have at the present moment in this inquiry, it seems to me, is to ascertain whether or not the liquid is a polluting one or not.

3573. It may not show grades of difference?—It may not show such grades of difference as we would like to; but it shows sufficient for the purpose. I need scarcely say that I prefer my own method, and that I think it is the best.

3574. (*Mr. Killick.*) Sir Henry will, perhaps, put in the table, my Lord.

3575. (*Professor Ramsay.*) The table would be a useful one to hand in.

Table 10 handed in by witness.

TABLE 10.

PERMANGANATE TEST, 4 hours:—Results of the Examination of Sewage Effluents.

COMPARISON of the Results made at a temperature of 60° Fahr. with those made at 78° Fahr.

Sanitary Authority.	Oxygen Absorbed. Grains per gallon.	
	60° Fahr.	78° Fahr.
Cheadle and Gatley, Sept. 1896	0·08	0·18
Offerton	0·34	0·45
Pendlebury	0·38	0·43
Gorton	0·46	0·39
Hindley	0·39	0·52
Marple	0·50	0·46
Astley Bridge	0·50	0·85
Northenden	0·55	0·68
Alderley	0·56	0·65
Ashton-on-Mersey	0·58	0·82
Hale	0·61	0·85
Wilmslow	0·62	0·82
Prestwich	0·63	1·29
Ashton-in-Makerfield	0·65	0·89
Knutsford	0·82	1·49
Dunham Massey	0·85	0·90
Bury	0·86	1·07
Prestwich	0·85	1·64
Swinton	0·92	1·20
Timperley	1·00	1·23
Worsley	1·01	1·35
Average of 21 tests	0·62	0·86
Flixton	1·49	1·91
Manchester	2·00	2·29
,,	2·05	2·43
Gorton	2·30	2·66
Swinton tank effluent	2·27	2·64
,, ,,	3·97	4·20
,, Cinder and land	0·62	1·01
,, ,,	0·94	1·23
Pendlebury land	0·84	1·03
,, Raw sewage	6·78	7·81

	60° F.	78° F.	120° F.	212° F.
Manchester (tank effluent).	1·39	1·67	2·60	5·15
,, ,,	1·34	1·62	3·34	4·97
,, ,,	1·07	1·27	—	2·87

FRANK SCUDDER, F.I.C., F.C.S., for Sir Henry Roscoe.

3576. Then you regard this as a means of determining organic matter—this oxygen absorption; is it always certain that the dangerous organic matter is most easily oxidised?—I think so. I am prepared to say that it is not always the measure—that is you may have a liquid capable of undergoing putrefaction which does not show by this means, nor indeed does the test, which we now usually employ, and which I think has been generally accepted, that which is called the incubator test, always show the same thing.

3577. Would you mind describing the incubator test, Sir Henry; we are not aware, I think, what it is?—I will. The test, which is known as the incubator test, and which, was first used in our laboratory in Manchester so long ago, indeed, as 1895, is the following:—To place a bottle filled with the liquid, and closed air-tight; to expose that liquid which is placed in the bottle to a temperature of 75° for five to seven days. In many cases a liquid thus treated does not putrefy, because the microbic life necessary to produce putrefaction is either not present or not active, and therefore in all cases the incubator test must be strengthened and controlled by chemical analysis, namely, the determination of the free and albuminoid ammonias, and the determination of oxygen absorbed from permanganate of potash, and then, if these are beyond a certain amount, I should certainly not pass the effluent. And I think that I may shortly say that the incubator test is not merely a qualitative test—that is to say, it is not merely to know whether the liquid put into a bottle in this way, and heated up in the incubator for a certain time at a certain given temperature, becomes offensive and putrefies, but the amount of putrefaction can be tested—that is to say, the amount of the oxygen absorbed before treatment and after treatment can be ascertained, and thus the test becomes not only a qualitative one for putrescence, but an absolutely quantitative one for the amount of the peculiar putrescible bodies, and that is shown on a diagram which I hand in, giving the amount which is found both before and after incubation.

Note.—Diagram handed in and marked Z. Appendix No. 18 (I).

3578. Then, as regards the permanganate tests, on page 302, Nos. 3 and 4; is there any relation between those two? Do you find that if the one goes up, the other also goes up, and *vice versâ*?—Yes, but they do measure different things.

3579. They measure different things?—They measure different things. The oxygen absorbed from permanganate, or what we call the three minutes' test, measures the amount of putrescible matter capable of instant oxidation. And the fact is, that those two determinations go hand in hand, and one is as important as the other.

3580. Is there any relation between those and the albuminoid ammonia?—Not necessarily.

3581. Do you regard the two permanganate tests as differentiating two kinds of albuminoid ammonia?—Yes. I regard the determination of albuminoid ammonia as important, as showing that the oxygen test is not always reliable. I have a curious instance of that in the case of the sewage from a place called Reddish. There it was found that in four samples the four hours' test varied from 1·29 to 21·22, whilst the albuminoid ammonia varied from a very small amount, ·021, to another small amount, ·098. The question was, how is it in this particular sewage the quantity of oxygen absorbed is so extremely high, while the albuminoid ammonia is so comparatively low, and within what we term our limit? And it appeared on examination that this was due to the presence of carbolic acid which was present. And in the same way, I might refer to a case of manufacturers' waste in Manchester, where the same thing held good; thus, for example, in Manchester the sewage was analysed the three minutes' test in the years 1894, 1895, and 1896, and the average of this was 2·03 for 1894, 1·86 for 1895, 2·06 for 1896—that is to say, you may call it roughly two, the average of the three years before the manufacturing effluent was put in. When the manufacturing effluent was put in—that is when the sewers were connected up with a number of manufactories, we found that the average for 1897 and 1898 rose up to twice the amount, namely, 4·03 and 4·29, and I may add that the three minutes' test showed a still greater difference. Well, that showed the effect on the oxygen test of the introduction of manufacturing effluents, and therefore also shows the necessity of accompanying the oxygen test with the albuminoid ammonia.

3582. But I have no doubt you know, Sir Henry, that many people contend that the albuminoid ammonia test is valueless, inasmuch as urea is not affected by it, and various other nitrogenous compounds to be found in sewage?—There is no doubt that you may pick holes in all these methods, but urea as such is not found in sewage; it has been converted into ammonium carbonate.

3583. They are arbitrary methods?—Quite so; but they serve the purpose we have in view.

3584. Combined chlorine is another point which is

mentioned in some of the analyses?—Well, I do not think I mention it, do I?

3585. Chlorine generally?—Chlorine generally.

3586. I should like to ask your experience as regards this. Is it quite certain that when chlorine is estimated—I mean to say, when silver nitrate is added to a water, that chlorine is estimated? We have been making some analyses, which would seem to show that chlorine disappears?—That I am not aware of.

3587. You cannot throw any light upon that?—No, I cannot throw any light upon that. The quantity of chlorine, of course, does increase with the amount of sewage put in, and decreases when the sewage is diluted with spring or rain water. It is more a measure of the domestic sewage than anything else; at the same time, I do not attach very great importance to it.

3588. I see you do not think it is a matter of importance, this estimation?—Not of very great importance. Of course, the effluent from a filter bed will contain the same quantity of chlorine as the effluent that goes on to it.

3589. That is the point; it does not.—It does not?

3590. No, by no means; it loses a great deal?—Well, that I am not prepared at this moment to speak upon.

3591. Then, as regards standards of purity, on page 7 you have advocated the impossibility of fixing standards for sewage effluents?—Yes.

3592. And you contradict yourself by making standards. I suppose you regard it as a practical necessity to have some sort of standard?—I do not propose to make a standard for manufacturing refuse, in the first place.

3593. But for domestic sewage?—For domestic sewage. I say that you must draw the line somewhere, and I have drawn the line under certain conditions.

3594. Does not that practically make a standard?—No. I would like to explain to you why. Whilst fixing a limit beyond which the liquid becomes a polluting liquid, there is no reason why a still lower limit should not in some cases be reached.

3595. Quite so, yes?—And I will give you an instance of that. Take, for example, the effluents from Manchester, and from a small district in the neighbourhood Stretford; in both cases we must get the sewage in such a condition that the limit is not passed, but in the case of Stretford we find that the effluents examined in many instances have been far below this standard—nearly half. Very well; in another instance we have found that the Stretford sewage has gone up—up to the limit. To say to Stretford, "You shall only come up to the limit when you can do better" would be obviously absurd. To say to Manchester, on the other hand, "You shall do what Stretford does, and you shall keep down below the limit as Stretford does," is also absurd, because Manchester cannot do it, and therefore what I say is that although you must draw the line somewhere, it is not a fixed standard in that sense that you are never to go below, and always going to be satisfied with coming up to that line.

3596. But is not that very much the same state of matters as with the Alkali Act, the turning out of polluting gases into the air; they have variations of that sort?—No, the cases are not parallel.

3597. Where is the difference?—In this case the sanitary authorities ought not to be satisfied without getting the best they can out of the system.

3598. But is not that the case with the alkali inspector, too?—I am not sure, because if they are below the limit it is all very well; but they are not bound to go as low as they possibly can work. It may be desirable; they may do it for the purpose, but I say we will not have any standards at all except this limit, because our object is to use "the best practicable means," and if Stretford can do better than the limit, then it ought to be made to do so. With regard to that I would like to draw attention to a leaflet which was circulated and signed by Mr. Killick, the Chairman of the Consulting Sub-Committee of the Mersey and Irwell Watershed Committee. I will only read one paragraph with regard to these limits of impurity, and it is as follows:—"These limits of impurity are based upon experimental evidence, proving an effluent below or up to them would not putrefy when discharged into small streams, or into sluggish waters, such as the Manchester Ship Canal, but above them putrefaction would arise, and it may be observed that at all sewage works in the watershed where only chemical treatment is adopted the effluent is almost invariably above, and, on the other hand, where sewage works adopt filtration the effluent is below those limits."

3599. So that your proposition, so far as I understand it, is to lay down a broad limit above which the impurities shall not reach, but at the same time to take every means in your power to induce the towns to go as low as they can in the way of impurity?—Yes, that is so. For instance, I find that on one occasion—I refer to Table 3 on page 305 of my précis—I take the case of Wilmslow. There on one particular occasion the four hours' test showed an amount of oxygen absorbed of 1·23, but on previous occasions I find that the quantity of oxygen absorbed is in some instances only one-tenth of that amount, and that the average of a large number of instances is very much less—half of the amount found on that previous occasion. Hence, then, I say, "You at Wilmslow can evidently, if you take pains, do very well, and it is not sufficient for you, and it is not enough to ask you simply to keep to the limit, but to do the best you can," and many of these authorities admit that, and are willing to work much below the standard or limit.

3600. (*Mr. Killick.*) In other words, Sir Henry, while you have these standards or limits of impurity, you wish the authorities to carry out the words of the Act; that is, that they shall use "the best practicable and available means"?—That is exactly what I wish.

3601. (*Professor Ramsay.*) There are only a few questions as regards methods, Sir Henry, which I should like to ask you about. The analyses relate to pure sewage, I suppose?—Yes.

3602. To filtered sewage?—The analyses?

3603. I mean in making the analyses the sewage or the effluent is filtered before it is analysed, is it not?—Oh, no, certainly not.

3604. It is analysed on the crude?—It is analysed as it is sent in.

3605. As it is sent in?—As it is sent in; that is to say, when there is a deposit the deposit is analysed with the clear liquid.

3606. With the clear liquid; that is what I wanted to be sure about?—That is very important, because in a great number of cases the more deleterious portion and the more putrescent and putrescible portions of the sewage are found not in the liquid, but in the suspended solids.

3607. I noticed that the total nitrogen is not estimated in any of your analyses, I think?—I have a great number of experiments on this point; I do not know whether it is worth while to go into the detail of it, but if you desire to do it I could show you a number of analyses giving the difference between the amount of ammonia found in the clear liquid and in that which is shaken up, and to compare the quantity as found by the ammonia process of Wanklyn with that determining the organic nitrogen by Kjeldahl. I have a great number of analyses of this kind, which I now put in. (Analyses put in.)

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17 Jan. 1899.

EXPERIMENTS CONDUCTED WITH A SAMPLE OF SEWAGE EFFLUENT FROM MANCHESTER SEWAGE WORKS.

A number of Bottles filled to the stopper with Sewage Effluents were put into the Incubator for following Tests :—

(1.) Shake up well one bottle and analyse.

(2.) Analyse clear liquid, only without disturbing sediment, in separate bottle from No. 1.

SUMMARY OF ANALYSES.

TABLE K., No. 11.

Date taken from Incubator.	Ammonia.				Organic Nitrogen. (Kjeldahl process).		Oxygen Absorbed.						Alkalinity H_2SO_4 required to neutralize.	Chlorine.	Nitrates and Nitrites as N.	
	Clear.		Shaken.				3 minutes test.		Clear 4 hours.		Shaken 4 hours.					
	Free.	Alb.	Free.	Alb.	Clear.	Shaken.	Clear.	Shaken.	Atmos.	Incub.	Atmos.	Incub.				
Original 13 Oct. 1896	—	—	1·55	0·18	—	0·780	—	0·40	—	—	1·97	2·92	1·22	10·9	0·147	Brown coloured, slightly turbid, smell of sewage, nitrites present.
16 Oct. 1896	1·95	0·117	1·85	0·196	0·181	0·340	0·31	0·47	1·44	2·45	1·70	2·01	0·00	—	0·016	Brown surface fungus, brown sediment, no smell.
19 Oct. 1896	2·03	0·089	1·69	0·159	0·167	0·401	0·38	0·46	0·84	1·12	1·48	1·85	0·00	—	0·000	Brown surface fungus, black sediment, liquid dark tinged, faint smell.
21 Oct. 1896	2·02	0·070	2·13	0·226	0·172	0·333	0·51	0·78	1·17	1·39	1·84	2·23	—	—	—	Black surface fungus, black sediment, liquid dark coloured, putrescent smell.
23 Oct. 1896	1·86	0·067	1·63	0·134	0·275	0·413	0·68	0·66	1·41	1·58	1·54	1·89	—	—	—	Black surface fungus, black sediment, liquid dark coloured, putrescent smell.
26 Oct. 1896	1·92	0·070	2·11	0·154	0·183	0·505	0·66	0·94	1·18	1·88	1·90	2·27	—	—	—	Surface fungus had fallen to foot, black sediment, liquid dark coloured, putrescent smell, H_2S present.

MICROSCOPICAL EXAMINATION OF DEPOSITS, &c.

13 Oct. 1896.—No life visible under ⅓" objective.
15 Oct. 1896.—A few forms like bunches of grapes rolling about, the sediment had developed a mould with long filaments.
16 Oct. 1896.—A few forms noticed amongst mould at foot. Surface fungus had developed zooglia and rotifera including one or two bell animalculæ.
19 Oct. 1896.—Great quantities of infusoria and rotifera, &c., present and long ribbons of zooglia on surface. Sediment had only a few forms, but a quantity of mould.
21 Oct. 1896.—Life not so plentiful as formerly, and in sediment only one or lower forms were seen. Spores were plentiful however.
23 Oct. 1896.—No life was visible, dead forms and spores were seen, and strings of zooglia were plentiful on surface.
26 Oct. 1896.—No life was visible.

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TABLE L., No. 12.

Date taken from Incubator.	Ammonia.				Organic Nitrogen (Kjeldahl Process).		Oxygen Absorbed Test.						Alkalinity as H_2SO_4.	Chlorine.	Nitrates and Nitrites.	Residue of Liquid after 1 Day. Oxygen abs. 4 Hours.		
	Clear.		Shaken.				3 Mins. Test.		4 Hours Clear.		4 Hours shaken.							
	Free.	Alb.	Free.	Alb.	Clear.	Shaken.	Clear.	Shaken.	Atmos.	Incub.	Atmos.	Incub.				Clear.	Shaken.	
Original, 20 Oct. 1896	—	—	1·32	0·137	0·539	0·539	—	0·47	—	—	2·05	2·61	0·	13·0	0·270	—	—	Nearly free from suspended matter, slightly brown and turbid.
23 Oct. 1896	1·50	0·095	1·45	0·129	0·321	0·298	0·47	0·50	1·61	1·72	1·78	1·94	—	—	0·013	—	—	Clear, colourless, brown sediment, brown surface fungus, no smell.
26 Oct. 1896	1·52	0·070	1·44	0·087	0·202	0·248	0·44	0·51	1·06	1·36	1·34	1·61	—	—	0·000	—	—	Clear, colourless, dark sediment, brown surface fungus, no smell.
28 Oct. 1896	1·51	0·083	1·45	0·140	0·275	0·454	0·37	0·47	0·90	1·11	1·25	1·49	—	—	—	0·65	0·87	Clear, colourless, dark sediment, brown surface fungus, no smell.
30 Oct. 1896	1·47	0·022	1·69	0·098	0·163	0·321	0·40	0·50	0·89	1·10	1·35	1·58	—	—	—	0·59	0·77	Faint, dark tinge, black sediment, surface fungus turning black, faint smell, but not putrid.
2 Nov. 1896	1·74	0·019	1·55	0·114	0·184	0·431	0·22	0·58	0·57	0·71	1·38	1·59	—	—	—	—	—	Faint, dark tinge, black sediment, greyish, black fungus surface, faint smell.

MICROSCOPICAL EXAMINATION OF SAMPLES.

20 Oct. 1896.—No life visible.
23 Oct. 1896.—Sediment had only a few forms of life, surface fungus had rotifera and other animalculæ in plenty, and strings of zooglia.
26 Oct. 1896.—Sediment had only a few forms of life, surface fungus had rotifera and other animalculæ in plenty, and strings of zooglia and fungus consisting of long hair-like forms.
28 Oct. 1896.—Sediment almost barren, surfac fungus had fewer forms than before but abundance of bacteria vibrione.
30 Oct. 1896.—Sediment barren, surface fungus had only a few infusoria, but strings of zooglia were in abundance.
2 Nov. 1896.—Sediment barren, surface fungus had only one or two forms of life, but strings of zooglia were in abundance.'

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EXPERIMENTS conducted with a Sample of Sewage Effluent from Manchester Sewage Works—*continued.*

Summary of Analyses—*continued.*

TABLE 13.

Date taken from Incubator.	Ammonia. Clear. Free.	Ammonia. Clear. Alb.	Ammonia. Shaken. Free.	Ammonia. Shaken. Alb.	Organic Nitrogen (Kjeldahl Process). Clear.	Organic Nitrogen (Kjeldahl Process). Shaken.	Oxygen Absorbed Test. 3 Mins. Test. Clear.	3 Mins. Test. Shaken.	4 Hours Clear. Atmos.	4 Hours Clear. Incub.	4 Hours Shaken. Atmos.	4 Hours Shaken. Incub.	Alkalinity as H_2SO_4.	Chlorine.	Nitrates and Nitrites.	Residue of Liquid after 1 Day. Oxygen abs. 4 Hours. Clear.	Residue of Liquid after 1 Day. Oxygen abs. 4 Hours. Shaken.	——
Original, 30 Oct. 1896	—	—	1·48	0·117	—	0·367	—	0·48	—	—	1·00	—	0·00	15·2	0·057	—	—	Sample fairly clear, very little suspended matter, neutral, tarry smell.
2 Nov. 1896	1·57	0·036	1·63	0·075	0·30	0·370	0·29	0·33	0·90	9·96	0·93	1·13	—	—	0·00	0·65	0·78	Brown sediment, brown surface fungus, clear and colourless, no smell.
4 Nov. 1896	1·66	0·061	1·78	0·119	0·31	0·480	0·44	0·45	0·80	1·11	1·08	1·32	—	—	—	—	—	Blackish sediment, brown surface fungus, clear and colourless, no smell.
6 Nov. 1896	1·43	0·059	1·83	0·144	0·112	0·212	0·46	0·60	0·66	0·97	1·08	1·32	—	—	—	—	—	Black sediment, brown, surface fungus, slightly tinged liquid, slight smell.
9 Nov. 1896	1·61	0·068	1·57	0·109	0·188	0·355	0·33	0·37	0·70	0·84	0·91	1·14	—	—	—	—	—	Black sediment, brown surface fungus just turning black, slight smell.
11 Nov. 1896	1·69	0·070	1·74	0·149	0·171	0·379	0·33	0·45	0·72	0·88	0·88	1·18	—	—	—	—	—	Black sediment, brown surface fungus just turning black, slight smell of H_2S.

MICROSCOPICAL EXAMINATION OF THE SAMPLES.

30 Oct. 1896.—No life visible.
2 Nov. 1896.—The surface fungus was swarming with life infusoria, vibrione, and bacteria, &c. The sediment had only a few forms.
4 Nov. 1896.—The surface fungus was swarming with life infusoria, vibrione, and bacteria, &c. The sediment had only a few forms.
6 Nov. 1896.—The surface fungus had great quantities of hair-like filaments, also infusoria zooglia, &c. The sediment had no forms.
9 Nov. 1896.—The surface fungus was one mass of hair-like filaments, with a few infusoria zooglia. The sediment had no forms.
11 Nov. 1896.—The surface fungus was one mass of hair-like filaments, with hardly a living form. The sediment had no forms.

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3608. There is only one other question I think I wish to ask. Has any attempt been made to differentiate between different kinds of organic compounds, except by means of the different times of oxidation with permanganate, and the differences of albuminoid ammonia and free ammonia—no other method?—I have a series of experiments giving the effect of the same test, not merely three minutes and four hours, but intermediate times, the object being, of course, to show the variation in the material capable of undergoing putrescence. The three minute test shows the putrid matter decomposing permanganate with acid at once, then the twelve minutes test shows the matter readily putrefying and readily decomposing permanganate with acid, and the 225 minutes or the four hours test showing the matter capable of putrefying although slow to decompose; but there is no other method that I know of that has been proposed for further differentiating the quality of organic matter.

TABLE 14.

The following Table differentiates the quality of the Organic Matter as estimated by the Permanganate Test:—

SALFORD SEWAGE EFFLUENTS.

Quality of Organic Matter as measured by Permanganate of Potash.

Oxygen absorbed from Permanganate of Potash—after

1894.	3 mins.	+ 12 mins.	+ 225 mins.	= 4 hours.
April 10	0·87	+ 1·07	+ 1·31	= 3·25
„ 13	1·13	+ 1·07	+ 1·52	= 3·72
„ 16	0·64	+ 0·81	+ 1·42	= 2·87
„ 19	0·66	+ 0·96	+ 1·50	= 3·12
„ 23	0·43	+ 0·52	+ 1·17	= 2·12
„ 25	0·56	+ 0·65	+ 1·24	= 2·45
May 22	0·69	+ 0·51	+ 1·24	= 2·44
„ 23	1·07	+ 0·59	+ 1·35	= 3·01
„ 24	1·38	+ 0·65	+ 1·63	= 3·65
„ 25	1·42	+ 0·54	+ 1·38	= 3·34
Sept. 10	1·23	+ 0·58	+ 1·28	= 3·09
Oct. 2	1·07	+ 0·75	+ 1·83	= 3·65
„ 12—10.0 a.m.	2·01	+ 0·57	+ 1·30	= 3·88
„ 12—11.0 a.m.	1·81	+ 0·58	+ 1·27	= 3·66
„ 15	2·14	+ 0·62	+ 1·37	= 4·13
„ 23	0·63	+ 0·50	+ 1·54	= 2·67
„ 31	0·37	+ 0·32	+ 1·40	= 2·09
Nov. 7	0·49	+ 0·65	+ 1·53	= 2·67
„ 16	1·45	+ 0·57	+ 1·49	= 3·51
„ 22	2·0	+ 0·48	+ 1·41	= 3·89
„ 30	0·88	+ 0·5	+ 1·1	= 2·48
Dec. 11	1·67	+ 0·7	+ 1·67	= 4·04

SALFORD SEWAGE EFFLUENTS.

Quality of Organic Matter as measured by Permanganate of Potash.

Oxygen absorbed from Permanganate of Potash.

Percentage Absorption of Oxygen.

Calculated from analytical results.

1894.	3 mins.	+ 12 mins.	+ 225 mins.	= 4 hours.
April 10	26·8	+ 32·9	+ 40·3	= 100
„ 13	30·4	+ 28·8	+ 40·8	= „
„ 16	22·3	+ 28·2	+ 49·5	= „
„ 19	21·1	+ 30·8	+ 48·1	= „
„ 23	20·3	+ 24·5	+ 55·2	= „
„ 25	22·9	+ 26·5	+ 50·5	= „
May 22	28·27	+ 20·11	+ 50·82	= „
„ 23	35·54	+ 19·61	+ 44·85	= „
„ 24	37·80	+ 17·55	+ 44·65	= „
„ 25	42·51	+ 16·18	+ 41·31	= „
Sept. 10	39·80	+ 18·78	+ 41·42	= „
Oct. 2	29·31	+ 20·56	+ 50·13	= „
„ 12—10.0 a.m.	51·80	+ 14·7	+ 33·50	= „
„ 12—11.0 a.m.	49·45	+ 15·85	+ 34·70	= „
„ 15	51·81	+ 15·02	+ 33·17	= „
„ 23	23·60	+ 18·73	+ 57·67	= „
„ 31	17·70	+ 15·3	+ 67·00	= „
Nov. 7	18·35	+ 24·35	+ 57·30	= „
„ 16	41·31	+ 16·24	+ 42·45	= „
„ 22	51·41	+ 12·35	+ 36·24	= „
„ 30	44·35	+ 20·17	+ 35·48	= „
Dec. 11	41·33	+ 17·34	+ 41·33	= „

22 tests.

3609. Would you regard it as a good test, generally applicable to sewage, if it could be made easy to find out whether it is capable of putrefaction. Would you regard a sewage as good which had been proved not to putrefy further?—How proved; by what test?

3610. By seeding it with organisms?—By the incubator test.

3611. Something of the kind?—No, I do not think it is sufficient. I do not think the incubator test alone is a sufficient proof of the deleterious quality. I think it is necessary to have some corroborative test as well.

3612. If organisms were added to the incubator, would it not be possible?—There might be cases where it would not even then do it. There may be substances present in the sewage which might stop the action of the organisms—carbolic acid, and so forth, and yet the liquid might

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be a putrefying liquid, or, at any rate, might be a deleterious liquid—a polluting liquid.

3613. But I suppose, generally speaking, if the effluent will not undergo any further change, it may be regarded as good?—Well, I do not know, I am sure, in what way it may be regarded as not undergoing further change. If you could prove that in all conditions and mixed with all sorts of other liquids, it would not undergo any further change, it might be so; but I think it is a doubtful case—at any rate, I have not been able to do anything of the kind.

3614. (*Professor Foster.*) In answer, Sir Henry, to a question put by Professor Ramsay you admitted that the so-called albuminoid ammonia test was not wholly trustworthy?—I admitted that in some cases other corroborative tests must be employed.

3615-16. That there are substances nitrogenous in nature, and even using the word very broadly, albuminoid in nature, which did not respond to that test?—That is so.

3617. And the presence of them in the filtrate would escape notice?—By that test.

3618. And you also admitted that your oxygen test was not in all cases reliable?—It was based on the view that the oxygen was absorbed by the oxidisable organic matter, but there might be substances greedy of oxygen which made their appearance from time to time, so that neither of your tests are reliable?—The tests do not intend and do not pretend to be absolutely scientific tests. They are tests of a practical character, and I think that in 999 cases out of 1,000, bearing in mind that we have to deal simply with sewage effluents, I think we might say that in 999 cases out of 1,000 the method of analysis that I have proposed, and that which is in vogue, does give sufficiently accurate results. It does not pretend to be an absolutely scientific method.

3619. You say 999 cases out of 1,000; that is not based on statistical evidence, but it is a pious opinion?—It is an opinion which I certainly entertain upon the results of my examination of sewage effluents.

3620. Suppose there were ready practical methods of determining in the effluent the presence definitely of albuminoid, and which could be applied only to substances of an albuminoid nature, you would be willing to admit that was a better test than the present albuminoid ammonia test, which is a superficial one, so to speak?—Of course, one must know what the new method is. The resources of civilisation are not yet exhausted, and I do not suppose that the methods that we have at present are going to remain for all time as the best; and it may be, as you say, that to-morrow some method may be proposed which is better, and therefore if such methods are proposed and prove themselves to be more efficient, why, of course, they would be adopted. All I say is I do not know any method at present.

3621. But would you admit that it is a desideratum?—I think, as I have said, that the methods that we do adopt, give us a sufficiently satisfactory result to be relied upon. Whether any further method might be better remains in the bosom of futurity. I should be glad to see a better method proposed, of course.

3622. We had before us a statement by Dr. Adeney, of Dublin, in his evidence, that he had reason to believe that part of the organic matter in sewage could assume a condition in which it was no longer putrescible, by which I suppose he meant that discharged, for instance, into a river, it would not decompose either spontaneously or would not be thrown into a state of putrefaction by any organisms which might be present in that river. I understood you to say, in reply to Professor Ramsay, that you do not believe that organic matter does fall into that condition—the organic matter present in sewage?—Well, I do not know that I can contradict the statements that Dr. Adeney has made. At the same time I do not profess to father them or to adopt them.

3623. But it is rather an important point, is it not, whether the organic matter in sewage can exist in the condition in which it is no longer susceptible to putrefaction under such conditions as it is likely to meet with?—No doubt it is an important question, but what we have to determine are not the innocuous constituents (if they exist), but the noxious ones.

3624. He asserts that a certain quantity of the organic matter in sewage is in the natural process of events brought to that condition, and that that matter may be discharged into the streams without danger?—If that can be done, if the organic matter can be brought into a condition in which it does not putrefy, no doubt the question assumes a different aspect; but I have not myself any evidence to show that.

3625. You yourself have no experience of that?—No. Besides, I might point out that no process of purification can get rid of the whole of the organic matter, and that below the limits which I have alluded to there is always in the effluent certain organic matter, and that organic matter is probably the kind—maybe the kind to which you refer.

3626. You say that no process can get rid of—what do you exactly mean by get rid of?—the organic matter?—Well, I mean oxidise. By the processes of purification which have hitherto been adopted, whether with chemical precipitation or of filtration, there is always a certain amount of organic matter left behind, and the object that I think most of those who have investigated this matter have had in view is to ascertain the quantity of impurity, and to get rid of that quantity—of the kind of impurity which produces putrefaction. If there are other kinds of impurity, organic matter or otherwise, which do not produce putrefaction, those I have not considered.

3627. Yes, but that is Dr. Adeney's point, that of the various organic matters in sewage; some are or come to a condition that they are no longer susceptible of putrefaction under usual conditions?—Well, then, of course, if that be so—and I am not prepared to say whether it is so or not, except that I think it very possible—then those impurities can be discharged, I presume, into rivers, the water of which is not used for potable purposes; but the object is to ascertain not the quantity of such constituents, not the quantity of those constituents—organic constituents—which will not putrefy, but the quantity of those which do putrefy, and that I undertake to show we do estimate.

3628. But the albuminoid ammonia process I suppose would apply equally well or equally imperfectly to the matters which do putrefy and the matters which do not putrefy?—Well, that remains to be seen, what those materials are. There are certain impurities which do not yield to the treatment for albuminoid ammonia of course. For instance, take the question of soap solution; we find that we take a solution of soap, and if we analyse that as if it were a sewage effluent, we find that whilst the albuminoid ammonia remains low, and does not indicate impurity, the four hours' permanganate test does indicate impurity. Thus the limit would not be passed in the determination of albuminoid ammonia, whereas the limit would be passed by the oxygen absorbed test. It shows that there are cases in which the one cannot be trusted, and other cases in which the second test cannot be trusted. If both were taken together I think you would obtain trustworthy results. The albuminoid ammonia is derived from the nitrogen of the organic matter, and the permanganate attacks the carbon of the organic matter.

3629. In your memorandum you spoke of sewage as being complex and variable in character?—Would you kindly give me the reference to that.

3630. Page 301?—Yes.

3631. And you state, I think, further on that no dependence can be made in consequence upon the ratio of the carbon to the nitrogen?—Yes.

3632. Have you any knowledge of what are the substances present in sewage?—No, not beyond the extent that I refer to some of the organisms.

3633. No, I mean as to what is the condition of the nitrogenous matter?—No, I do not know.

3634. And, for instance, what is the condition of a great deal of the carbon that does not belong to the nitrogenous matters?—No, I do not know.

3635. You have no knowledge of that at all?—No knowledge.

3636. It has been put before us by one or two witnesses, that in a very broad way the results of the change in sewage under the various modes of treatment might be defined as consisting of two stages, one in which the nitrogenous matters are brought to a condition of ammonia, and the carbon only together with the carbon in other matters set free as carbon dioxide, and a second test in which that ammonia is converted into nitrates?—Yes.

3637. Do you agree with that as a general statement—a broad statement of the changes going on?—Yes. I do not know that I should be inclined to give that definition in all cases, because I have shown that in some instances nitrates are formed and in other instances they are not.

3638. Then in what condition is the nitrogen discharged

in those cases?—Well, I presume it may be reduced even to the condition of nitrogen itself; at any rate, we do not always find it as nitrates.

3639. That would appear as a loss of nitrogen, would it not? I mean merely it may be, but do you expect that that can take place on a large scale?—Well, I cannot say; but I do say this, that the nitrogen is not as a rule oxidised into nitric acid, for in nine cases out of ten you may find no nitric acid in the effluent—from the filter bed—and you may find, indeed, that the effluent from the tanks will contain nitrates, while the effluent from the filter beds did not contain any nitrates. Thus, for example, I find in reference to this matter that in a report which I sent into the Manchester Corporation in 1896, on page 308, I show that the quantity of nitrogen contained as nitrates and nitrites in the tank effluent was ·109, in the cinder effluent after the filtration it was ·061, and in the coke filter after filtration it was ·069, so that the quantity was reduced actually by the process of filtration; the nitrates were reduced from the quantity that was found in the tank effluent to half nearly, and the year afterwards, that is to say, in 1897, we found that the quantity of nitrogen as nitrates and nitrites increased in the one filter and diminished in the other. So that what I say is this, that although it is generally said that in the oxidising action nitrates are formed, I often do not find them, if you look for them they are not there—and sometimes the quantity is absolutely less in the filtered effluent than it is in the effluent before filtration.

3640. Of course, it is not a comparison between the nitrates in the tank effluent and in the filtrate, but it is a question of what becomes of the nitrogen in the tank effluent. That nitrogen exists, I suppose, either as ammonia or compound of ammonia—some compound or other of ammonia—or as albuminoid matter, using that in the very broad sense, or as nitrites, or as nitrates. In what form does that nitrogen exist in the filtrate?—If you ask me a question of that sort I am afraid I cannot give you any definite answer. If you ask me, do I believe if the position you put before me is one which may be generally adopted, I say no. I do not think it is, because I find there are no nitrites and nitrates in the effluent; comparatively the quantity is not what you would expect it to be, and, as I say, I think it probable that a very considerable proportion of the nitrogen is evolved as such.

3641. As simple nitrogen?—Yes, I think so.

3642. In the filter?—Yes, I think so.

3643. Have you any evidence of that at all?—No; on this sort of theoretical point I do not pretend to give a distinct opinion, but what other form can it have? If it is not in ammonia, and it is not in the form of nitrites and nitrates, what other form can it have?

3644. Of course, in several analyses we have had before us there have been a considerable quantity of nitrates in the filtrate, and it has been stated that the quantity corresponds to the nitrogen in the material thrown upon the filtrate, showing that nitrification has taken place?—Well, that is not my experience. I think that the quantity of nitrates does increase considerably when the aeration of the filter is of long duration.

3645. With regard to these organisms which you and Mr. Lunt studied?—Yes.

3646. You spoke of several of them absorbing oxygen?—Yes.

3647. Not only the aërobic, but the anaërobic; but is it not the characteristic of the anaërobic organism from which it derives its name, that it works without oxygen?—Yes, that is so.

3648. These organisms that you speak of there, which obviously do absorb oxygen, must be the so-called facultative organisms?—Yes, I think so.

3649. Then I rather gather from what you state that you thought a chemical examination of the filtrates gave you all that it was necessary to know?—I did not intend to say so.

3650. Page 6; that was the sentence that was in my mind: "Suffice it to state that, in my opinion, purely chemical analysis is sufficient to afford a safe criterion as to the fitness of a sewage effluent to be discharged into a water course"?—Oh, yes, I adhere to that. I do not say that it is not advisable to add other methods in special cases; all I say is that the chemist can thus obtain sufficient evidence.

3651. Do you think that it is safe to discharge a number of pathogenic organisms through the filtrate?—No, I think that it is very unsafe.

3652. Can chemical analysis detect their presence?—No, certainly not; but I think that where you have got pathogenic organisms, you will also find in all cases a sufficient amount of chemical impurity to condemn your effluent.

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3653. What is your evidence of that?—That is my opinion. I may be incorrect about it, but, of course, if you have a method by which you can detect pathogenic organisms easily and well so much the better. At the same time, I wish to point out that all I am speaking of in this précis, and in my evidence, is with regard to the question of how far the liquids are polluting liquids. I do not propose to say that the tests that I am applying, or that I am anxious to see applied, suffice for the case of water which is to be used for drinking purposes—on the contrary. And, therefore, I do not know that the presence of pathogenic organisms would be so serious in the case of the water to which I have referred, and which I was considering, as it would be in the case of waters which were used for potable purposes.

3654. Is it safe to make the distinction between water which is potable and water which is used, for instance, for washing drinking vessels?—Well, you know all that I have had to do with, and that I have been speaking about, are almost entirely on the Mersey and Irwell Watershed. I have not entered into the question of the Thames, and the limits I should draw might be altogether different if I were considering the question of the Thames basin. I have only been considering the question of the Mersey and Irwell basin, and there I do not think that anybody would ever use the water for potable purposes, or even for washing their clothes.

3655. Well, let me put it in this way, Sir Henry; do you not think it is advisable, considering that it can hardly be considered as proved at present, that pathogenic organisms cannot exist in a filtrate without a correspondingly large quantity of organic polluting matter, that it is desirable that the filtrates should be examined from a bacteriological, and not entirely from a purely chemical point of view?—Oh, I certainly agree with that view respecting water which is capable of being used, which is being used, or which it is possible to be used, for potable purposes—domestic purposes; certainly I think if a method can be found for ascertaining by a bacteriological examination whether any of those pathogenic organisms are present, I think it most important that that examination should be made.

3656. But it is not in all cases desirable?—No, I do not think it is necessary in all cases. I do not think it is necessary, for example, on our watershed.

3657. I mean how do you know where these germs may not be carried—by what indirect means they may not get back again?—Yes, I quite agree there and then, I say; I think if you can find out a method by which it can be readily done I shall be very glad to adopt it, and I think it ought to be adopted, but hitherto I must confess I have not been able to find out an easy practicable method by which the presence of pathogenic organisms can be detected in the sewage water. I do not know how it could be done; if it could be done readily I certainly say it ought to be adopted.

3658. You are speaking now of your own experience?—My own experience, of course, and of the conclusions to which others have arrived.

3659. That nitrates from the filtrate will not give you the means of detecting pathogenic organisms?—No, but I have not been able to find out a method which is practically applicable; I shall be happy to learn it.

3660. (*Sir Richard Thorne.*) I know, Sir Henry Roscoe, that the Commission were anxious to get your advice even outside the Mersey and Irwell basin; therefore I think you will not mind me asking one or two questions bearing on Professor Foster's?—To the best of my ability.

3661. When you spoke of chemical analysis affording a safe criterion may I assume that you did not mean from a public health point of view?—No, I did not mean from that point of view; it certainly is necessary with water which is to be used for potable purposes that bacteriological examinations should accompany a chemical examination.

3662. From that point of view of the term you did not mean the same?—What I meant was that from the point of view of the Mersey and Irwell Joint Committee, a chemical examination is sufficient. If you ask me whether this suffices for a water used for drinking purposes, I at once say no. There we need a bacteriological examination as well, and if this shows the presence of such organisms

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as coli communis, etc., that water should be condemned even if its chemical analysis was satisfactory.

3663. With regard to chemical analysis being sufficient for your purpose may I just ask your view as to a passage which I am quoting out of the last report of the Medical Department of the Local Government Board. Dr. Klein and Dr. Houston were engaged to ascertain, in so far as chemical and bacteriological examination of water was concerned, what was the effect of adding pathogenic organisms. To refer for example to experiment No. 5. Here sewage was added to the water in the proportion of 0·1 per cent., which sewage, as the bacterioscopic analyses show, contained in its crude state a comparatively small amount of bacillus coli and bacillus enteritidis; nevertheless there was no difficulty in demonstrating in this diluted sample the presence of both those microbes; meanwhile, chemical analysis in its turn of the particular sample indicated a water of great organic purity?—Yes.

3664. That would rather confirm, then, what you say as to your tests named in your evidence: "It must be distinctly understood that this definition of a polluting liquid does not apply to a case of a sewage effluent flowing into a river or water which is used for drinking purposes"?—Yes. Of course I am not a bacteriologist, and I yield both to you, Sir Richard, and to Professor Foster in the matter, but I understand that it is a fact that it is extremely difficult to detect typhoid bacillus in the water.

3665. It was the spores of bacillus enteritidis in the instance I refer to?—I may be wrong, but I have understood that it was extremely difficult to ascertain the presence of the typhoid bacillus in drinking water, and as a matter of fact it is very difficult to say whether it has been found.

3666. Would that apply to the spores referred to?—I suppose so. I mean it is a very difficult matter to investigate, and in these questions we ought to have something that is ready to hand, and can be done without a vast amount of either time, or what I may call scientific accuracy. We want something that can be done quickly, and that anybody can do almost, because after all we only have to determine whether the liquid is a polluting liquid or not.

3667. Well, then, to make one other point clear. I think I understood you to say that if pathogenic organisms were present in any substantial amount there would be other evidence, I assume chemical, of the unfitness of the effluent?—I am speaking of sewage, not of drinking water.

3668. Now take the case of a town that discharges into its sewers a certain given quantity of excreta per diem, and the sewage effluent of that town is taken from a chemical point of view to be satisfactory. Now a typhoid epidemic comes, and the amount of excreta is not increased, but the quality is totally different. Should you expect any difference in the chemical results · the excreta are now specific; they were not so before?—Then in that case of course the danger to life from drinking such water would be very considerable.

3669. But what I want to get your opinion upon is this: should you expect chemically to be able to detect the difference in the quality of the sewage?—No, I do not think I could, but I venture to doubt whether the typhoid bacillus can at present be with certainty detected bacteriologically in crude sewage effluent.

3670. May I revert for one moment to the question of standards. I have been very deeply impressed since I have been on this Commission with the almost unvarying statements of experts that we ought not to adopt a standard, and yet every one of those experts adopts one for his own purposes. Do you think it would be in the first place possible to lay down a standard in which the first condition imposed was the present statutory one, namely, that the best practicable and available means should be adopted?—That I certainly agree with.

3671. I was going to ask you is that to be one of them?—This is one.

3672. Well, now, do you think it possible that, the best available method having been adopted, then to lay down that there shall be in addition certain chemical tandards such as albuminoid ammonia, oxygen absorbed, or any other. As a matter of fact, the best available method at the present moment, after twenty-two years' experience, leads to some of the foullest stuff getting into the rivers that it is possible to conceive?—Well, I should like to have particulars of that last statement of yours, Sir Richard.

3673. Well, I refer to actions that have been brought against towns for delivering filthy effluents into the rivers, where counsel have satisfied those who have sat in judgment on the matter that they have used the best practicable and available means, with the result that nothing further has been done. Is not something wanted beyond "the best practicable and available means," and could not one add some other conditions that taken altogether would constitute a fair general standard?—Well, in the case of town sewage, as I have already stated, I have fixed what I call a limit; and I explained that I consider that to be the limit of impurity which must always be attained, and in that sense there is a standard fixed as far as our basin is concerned.

3674. On the other hand, something is wanted that would in some cases go much higher?—Yes.

3675. But I mean, always presupposing that the best practicable and available means be retained as a condition, would it not be possible to add to that some chemical standards contrived so to speak on a sliding scale?—The great difficulty is this: take a stream like the river Irwell, you find that the water of that stream is of every degree of purity from the most beautiful, purest water at the top to the foullest stream at the bottom. On this stream you have a great variety of manufacturers; you have a great number of towns. If you compel the manufacturer at the lower end of the stream to adopt certain limits of standards which would be applicable to the manufacturer at the head of the stream, you are evidently proposing something which cannot be carried out.

3676. But you yourself would make him use the best practicable means?—Yes, in different circumstances.

3677. But the best practicable means in his case is that which he himself can carry out?—The best practicable and available means which can be carried out.

3678. So that you would insist upon the man at the lower end of the stream producing if he can a perfectly clear effluent?—Yes, if he can, but he is not to do it if he cannot, and if you fix a definite standard which would be suitable for the man at the top of the stream you are doing something which is much too stringent for the man at the bottom of the stream, and if you fix standards to suit the man at the bottom of the stream then they are together inapplicable to the man at the top of the stream.

3679. Certainly, if you have only one standard without sliding scale?—Therefore you must have a standard for each particular position of the stream, and each particular man must be judged of under that first clause, and you must rely upon that, and rely upon that only.

3680. But do you not rely upon the condition of the stream only, do you not say this is all that is reasonable in consideration of the conditions of the stream; so that where the stream is pure you insist upon a perfectly clear effluent, and where the stream is black you permit a more polluting effluent?—Yes, I do.

3681. If you make him provide the best practicable and available means?—Yes, but what are the best practicable and available means to the man at the top of the stream are not the best practicable and available means to the man at the bottom of the stream.

3682. I am supposing that the manufacturer, irrespective of his position on the stream can produce a perfectly clear effluent?—If a man at the bottom of the stream can produce a perfectly clear and potable water out of a black effluent which he receives then he is bound to do it, but he has a right to demand that a workable process for doing this, practical and available, is pointed out to him.

3683. Is that ever carried out?—But that is not practical; you may assume it is practical, but it is never carried out.

3684. Practical and practicable are two different words; the statutory one is practicable?—Yes, practicable; is it practicable for a man to distil all his effluent that he gets in? He will then get distilled water. You say that can be done. Yes, it can be done. A man can distil the whole of his effluent. It comes in like ink and goes out of the still a beautiful pure effluent. You say it can be done, but it is not *practical*. This must be applied with ordinary common sense as to what can be done in view of the district and in view of the manufactures of that district. You do not wish to so far impede the manufacturers and the industry of the district that the people would go away.

3685. Then I take it one of the conditions from which you judge an effluent is the state of the river in which it is discharged?—The state of the river as he obtains it is a part of the conditions under which he works.

3686. It is rather the state of the river as he receives it, then?—Yes, I have said so.

3687. Not the state of the river into which he sends his effluent?—You cannot compel a man who receives a river water which is very impure or highly discoloured to send out an effluent which is equal to the effluent sent out by the manufacturer at the top of the stream who has to deal with perfectly pure water.

3688. Then does that not practically mean that these black rivers must remain black?—No, if every man and every authority was made to do their best the river water would cease to be black.

3689. Because manufacturers will receive them black, and you do not insist that they shall send them in any other way?—I do want to do so, and we compel him to improve, but you have to deal with this question from a common-sense point of view. What is the object we have in view? The object is to make the rivers as little of a nuisance as we possibly can, but that must be consistent with supporting the industries of the neighbourhood. If you go to insist on conditions which it is impossible to carry out except to the detriment and destruction of those industries, then I say you are doing far more harm than good.

3690. That just brings me back to my point that one of the conditions upon which you judge an effluent is the state of the river at the point where the effluent goes in?—Yes.

3691. (*Professor Ramsay.*) Does it not make it exceedingly difficult to obtain convictions in cases of dispute where there is no definite standard?—We have not found it so. We have found in all cases we could get convictions where it is necessary. I think Mr. Killick will bear me out. I do not pretend to be a lawyer, but I think that is so.

(*Mr. Killick.*) It is so.

3692-3. (*Professor Ramsay.*) What sort of testimony is brought in favour of the best practical means?

(*Mr. Killick.*) We have put Sir Henry Roscoe in the box, or offered him several times, and the witnesses on the other side have not appeared.

3694. (*Sir Richard Thorne.*) With regard to the questions both of land and of artificial filtration, I gather that your opinion is that thus far there is no doubt that you cannot do without some chemical precipitation before the artificial filtration, and before the passing of the effluent on land?—Yes, that is so, that is I cannot bring before you now sufficient evidence to show that artificial filtration can be carried out successfully without previous subsidence or chemical treatment. Might I just continue? I believe the main good which is derived from chemical treatment is settlement; I mean that if we could get the solid matter settled out easily by mere standing that that would practically do away with all additions of chemical material, and I may add that I was on the point of determining that question on a large scale for Manchester; but I was unable to continue the experiments. I believe it is quite possible that by a proper arrangement of tanks, and without the addition of any chemicals, a sufficient amount of subsidence may be obtained; indeed I say here:—"It may, to begin with, be assumed that no amount of chemicals which can, with any show of reason, be added, is sufficient, or nearly sufficient, to convert the whole of the fœcal matter into harmless forms. Hence the use of chemicals can only be recommended for the purpose either of starting a process of purification, or of simply getting rid of the evil odour. The purification of the river, in which the sewage may remain for some length of time, must therefore be effected by natural processes. Of these by far the most important is the change produced by living organisms. The change thus carried on may be of a two-fold character; the one, due to the action of the organisms requiring free oxygen for their growth, has the result of rendering the organic matter inoffensive; the other, due to organisms which flourish in absence of free oxygen, gives rise to products which are offensive. It is, therefore, clear that efforts should be made to preserve and assist the life of such organisms as are capable of effecting this innocuous change, and to prevent the growth of such as yield offensive products. The oxygen, necessary for the growth of what may be termed the aërobic organisms, is usually derived from the air dissolved in all unpolluted running water. Sewage, however, is either entirely free from, or at any rate contains less dissolved oxygen than is necessary for the active growth of these aërobic organisms. In consequence of the absence of dissolved oxygen in the sewage, this has, during its passage to the outfall, already begun to undergo change of a putrescent character, owing to the growth of the putrefactive or anaërobic organisms. The products of this putrefactive change readily absorb free oxygen, passing into more stable forms, and therefore, when the sewage is poured into the river, it rapidly robs the water of its dissolved oxygen. If now the quantity of sewage thus poured in exceeds a certain proportion as compared with the river or fresh water, the whole of the river is deprived of its dissolved oxygen, and the aërobic growths are thus practically killed. Hence the addition of deodorants has for its object the destruction by chemical oxidation of the putrescent material, which not only causes the foul smell, but effects the removal of the free oxygen from the water of the river. This deodorisation is, however, only the first step in the process of purification; and, in order that growths necessary for the production of healthy change may flourish, the deodorised sewage must be brought into contact with the free dissolved oxygen needed for the respiration of the organisms. This, under proper conditions, is obtained from the large volume of unpolluted water with which the sewage is mixed. But should the river water either be insufficient in quantity, or have lost its oxygen by previous pollution, then the whole volume of water, after mixing with the sewage, becomes incapable of supporting the life of the aërobic organisms, and no further addition of an oxidising chemical can ever restore the river to its normal condition. The only natural remedy then remaining is the slow absorption of atmospheric oxygen at the surface of the water. It is thus seen that the chemical oxidation or deodorisation of the sewage is only a means to an end, that end being the presence of a sufficient quantity of free dissolved oxygen."

3695. Then on that principle you must retain the sludge, I suppose?—Yes, that is the unfortunate part of it.

3696. You do not see any way of getting rid of sludge, then?—The other way of getting rid of the sludge is that process which has recently been spoken of, but about which I do not know that we have sufficient evidence. It is known as the septic process.

3697. Yes, but that is not chemical treatment?—That is not chemical treatment, but that does get rid of the sludge.

3698. But I am going on your assumption that chemical treatment is necessary in advance; that retains the sludge difficulty?—That does.

3699. Whilst we were in Lancashire I was rather struck with the difference between one or two methods of dealing with sludge. In some instances the sludge was only removed from the tanks every third or fourth or fifth day; in one, at least, I believe it was removed every day. Now does not the fact of retaining the sludge in these tanks seriously add to the foulness of the effluent from that tank, because you are mixing all the deposited filth of one, two, or three days with the fourth day's sewage?—Yes, no doubt.

3700. Is it not a very improper thing, then, to leave the sludge of one day's sewage to be mixed up with the sludge of the next day's sewage?—No doubt, if the sludge could be removed every day it would be very much better. It is partly a question of cost, of course.

3701. Well, is it a question of cost? What we saw in one place was that the recent sludge of one day's deposit could be got rid of by an ordinary indiarubber squeezee in a very short time; but if you allow it to deposit, men have to go in with buckets and spades. Then it becomes not only a matter of cost, but of labour also?—Most distinctly it ought to be removed as soon as possible, as soon as it has settled out. I suppose the reason for allowing it to stand is that it gets more solid, and when it is in a liquid condition it cannot be handled. I presume that may be so, but it certainly ought not to stand in contact with the sewage longer than necessary.

3702. I think all your references to land treatment have had regard to the broad irrigation, have they not?—By no means.

3703. You have given us no opinion about downward intermittent filtration, have you?—Yes, I have handed in to you my opinion upon that, but I have not much more to say upon that subject than is contained in this *précis*.

3704. What page is that please?—On page 310. We have had in Manchester a considerable amount of experience on that subject of intermittent downward land filtration.

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3705. It was the absence of details on page 310 that made me ask?—Perhaps I have not put much in about it. I shall be happy to give you any information I can.

3706. I should have liked to have got your view on it, that is all?—Yes. You will find, Sir Richard, in one of the reports which I put in, namely, that of 1896, a number of tables and diagrams giving the result of the analyses of land filtrates. If you desire it I can go into the detail, but if not I would refer you to that.

3707. No; I would rather have got your general view as to the application of the system of downward intermittent filtration to ordinary town sewage?—Yes, that you will find in the report, and I may say that the question entirely is one which can only be judged of in each particular case. I mean to say that whilst intermittent land filtration is available and successful in action in certain cases, it is absolutely inapplicable in others. If we take, for example, the case of Manchester, there the amount of dry weather sewage is 26,000,000 gallons. Under the Orders of the Local Government Board, the Manchester Corporation were bound to make provision for a rainfall of half-an-inch. The area which Manchester covers is 3,700 acres; upon this half-an-inch of rain means something over 60,000,000 gallons, therefore the quantity of water which the Manchester people may have to deal with amounts to something like 60,000,000 to 70,000,000 gallons a day.

3708. Now, if you are going to put that on to the land, and if you are going to get a satisfactory effluent from that land, you have to use a very considerable area. Thus, for example, it would come out that you would require at least 460 acres for that flow.

3709. Yes; I was not thinking of Manchester. I should imagine myself that it would not be very easily applied there. I was rather thinking of it generally; any view you might have as to the value of that system of filtration?—There is no doubt that land filtration is an excellent system where you can adopt it, but I say there are a great many cases in which you cannot adopt it.

3710. But that system requires much less land, of course, than the broad irrigation does?—Yes.

3711. And if a sufficient amount of land could be obtained in the district to secure a downward intermittent filtration system, would you regard that as preferable to any other form of filtration?—If the land can be obtained in quantity sufficient; if it is suitable, because it must be suitable as well as in area sufficient; and if the rainfall in the neighbourhood is not very serious, I think such filtration is very excellent.

3712. Of course, I am speaking now of the downward intermittent filtration, not land treatment generally?—Quite so; I am also speaking of the downward intermittent filtration.

3713. The rainfall is an important point?—The rainfall is a point upon which I think much stress has to be laid.

3714. (*Major-General Carey.*) As to the capacity of the experimental tanks at Davyhulme, can you say what the capacity of the filter when empty was?—Yes, I have got all that. I think you will find that on page 308.

3715. The figures you give at page 303 represent the water capacity?—Yes, they do.

3716. Can you give the original capacity?—The original size of the tank, yes.

3717. What I want is the reduction of the capacity when the filter is charged?—It is 12ft. 6in. by 18ft. by 3ft. deep.

3718. That is about 4,218 gallons, I make it. Then the 1,720 or 1,760 gallons represents the reduction after being filled with the sewage?—Yes, that is so.

3719. That is not quite one third?—Yes.

3720. Then there was a subsequent reduction for some months?—Yes, there was.

3721. Until the filters were matured or in working order?—Yes, I think so.

3722. And after that period it may be further reduced for several months I suppose?—Yes.

3723. There is no further sensible reduction; that is in the Manchester case that you were quoting to-day?—Yes, that is so.

3724. But you are not prepared to suggest any proportion as representing the reduction for the working capacity of a filter?—No, not beyond what I have stated. You have the figures giving all these details on page 308 in the report on the capacity of the experimental filter beds at Davyhulme.

3725. And then they go down to a certain point, down to March 23rd, 1896, down to May the 27th?—Yes.

3726. But that is not the limit of reduction; that merely happens to be to a certain date?—No; but the statement which I made on the results of Mr. Fowler's subsequent examination goes to show that the diminution which had taken place up to May, 1897, did not continue, and that since May, 1897, those filters have only lost 2 per cent. up to December last, so that it would appear that whilst the loss up to 1897 was considerable, that then the mass had got into a stable condition, and did not alter up to the present time.

3727. Can it be assumed from that that a filter takes fifteen months before it arrives at this stable condition?—Well, that is the conclusion that one comes to from these facts.

3728. Of course it is most important that we should have those data?—Well, the unfortunate part of the whole subject is that the data which you look for, and naturally and properly require, are so recent that it is exceedingly difficult to get any experiments lasting over a sufficient length of time. Here all I can say is that whilst these particular filters which were made by me diminished in capacity down to May, 1897, since that time they have not altered in bulk. How far that is to be taken as a general rule, of course it is not for me to say. I mean I do not pretend to show what the conclusion that you have got to draw from that is.

3729. Of course on those data really the whole design for the filters must be based, whether they are artificial filters that you have been using at these experimental works or bacterial filters?—It must no doubt have an influence, but I would call your attention to the fact that these filters are now passing—at the moment passing—as much liquid through them now as they did to begin with.

3730. That is after chemical treatment and precipitation?—Yes, always after treatment and subsidence. Although the capacity has somewhat lessened, their filtering power is equal to what it was to begin with in consequence of their treating more sewage than they did to begin with. They pass more liquid on to them, and they get an equally good filtrate or effluent out from them as they did to begin with, therefore the loss of capacity is of little moment.

3731. But they do not get the same volume of filtrate?—Yes, they get the same volume.

3732. I thought they got an improved quality, but not the same volume?—They now get an effluent equal both as to quality and quantity to that obtained by me in December, 1896.

3733. That is by additional filling?—They put on more liquid; and although the filters do not contain as much as they did, they are capable of doing as much work as they did.

3734. Yes, but I thought that the Leeds experiments showed that there was a very serious reduction of capacity.

3735. (*Colonel Harding.*) That was dealing with crude sewage?—I am speaking of dealing with the tank effluent after precipitation and subsidence; a totally different thing.

3736. (*Major-General Carey.*) In those artificial filters from which you have taken samples of the effluent for analysis, has rest always been allowed for the filters?—Always, there has been a regular system adopted. For example, this is the record of the time in working the filters, taking the total of 100 hours, then the percentage was as follows:—In the first place 1-10th of the time was taken in filling, 20 per cent. of the time it was resting full, 10 per cent. of the time it was emptying, and 59 per cent. of the time it was aerating; that is to say, it was empty. Making a total of 100 hours. I could give you the other numbers for other times, but that shows that always there was a period of filling, a period of emptying, a period of resting full, and a period of aeration.

3737. When you say that sewage can be treated at a maximum rate of 800,000 gallons per acre of filter that would apply to the filter when first started. You are not making any allowance there for reduction of capacity?—I have shown that so far no allowance is necessary.

3738. It may be reduced as you have already shown on page 308?—No allowance is necessary, because the filters are working now just as well as they did to begin with. Mr. Scudder reminds me that when the capacity began to

diminish, and when we only put on the quantity of sewage which we put on to begin with, then, of course, the quantity of effluent diminished, and we were only able to get, in the one case, instead of 800,000 we only got 735,680, and in the case of the coke filter only 687,280, so that there was a diminution of course when the capacity of the tanks had diminished by from 12 to 20 per cent.; there was a diminution in the volume of effluent filtered (see page 308, Table M).

3739. Then you show again an increase by increasing the number of fillings?—That is so. The fact was that during the time that we were working the filters had only three fillings a day in the twenty-four hours; they now find that they can put on four fillings.

3740. May that be taken as a permanent addition?—So it appears; they have gone on that way for some time.

3741. Then, as to another figure, 60,000 gallons per acre on land, that is after chemical treatment and precipitation?—Well, there again I must refer you to a table contained in a report for April 17th, 1896, and this number to which you refer was obtained from experiments made on the land filter at Davyhulme, 21 acres in area.

3742. That is on a very porous soil?—It is a fairly porous soil.

3743. Is 60,000 gallons the dry weather flow of sewage, or sewage mixed with rain water?—Well, of course, it depends entirely on what the weather was. Unfortunately, in all these towns we have to take the rain water when it comes.

3744. I mean whether that proportion that you have given of 60,000 gallons per acre is not excessive for certainly the majority of cases of land treatment, where the sewage is treated on land by intermittent filtration after chemical treatment. Have you known any instances, except on the land in Davyhulme, where that quantity of sewage has been efficiently treated after chemical precipitation?—Well, this land will take that quantity after chemical treatment.

3745. At Davyhulme?—At Davyhulme.

3746. Are there any other places?—That I cannot tell you; that I do not know.

3747. Then, going back to the question of the reduction of water capacity, the cases of bacterial filters where the crude sewage is put on to the filter without any chemical precipitation, would you expect even a larger reduction than has taken place in your experimental filters at Davyhulme?—I do not think I said so, did I?

3748. No; I am asking you?—Oh, I beg your pardon.

3749. In the instances where crude sewage is put direct on to the filters?—No doubt I should expect to find that the filter would require cleansing more frequently, and, of course, that the quantity of suspended material brought in would be larger and kept in the filter. For we then have sent on to the filter not only the insoluble organic matter of the sewage, but the large quantity of mineral matter—detritus—washed off the streets.

3750. And that the filter might not recover so rapidly as in the cases where the sewage had been previously treated and precipitated?—I have not any figures on the subject.

3751. (*Sir Richard Thorne.*) May I ask you one question in reference to your answer to General Carey, as to the water capacity of the filters that you have experience of? Should I be right in putting it in this way, that your view is this: That the diminution in the liquid capacity of the coke filter is compensated for by an increased purifying capacity?—I think it might be put so, yes.

3752. Is that what you mean?—Well, I had not ventured to say so exactly, because I was not quite sure whether we could put it more than we did put it to begin with. You see we did not try whether we could have worked it with four fillings. At that time we tried it with three, and we were satisfied with the three; it might have been that it would have stood four at that time. It might also have been that it would not have stood four at that time.

3753. I thought you said you put the same amount on now as originally?—Yes. What I said was that the report that I referred to of the work that had been done in the last month, was to the effect that they increased the quantity of sewage put on in the proportion of three to four because they filled up four times in the twenty-four hours, whereas we only filled three times in the twenty-four hours. I am not sure whether I can say that the filter is working better than it did when it was first inaugurated. In order to be able to know whether that was so or not I should have put on as much liquid as they are now putting on. I did not do so.

3754. That was my point. Then you cannot answer it?—No; but at all events the filters are now filtering as much as they did to begin with.

3755. (*Mr. Killick.*) The limit of impurity to which you have referred in the Mersey and Irwell watershed was to cover the greatest amount of impurity that an authority should be allowed to turn nto the stream of sewage effluent?—That is so.

3756. Do you believe that there has been a single case in the watershed where a sewage could not be purified to this degree?—I think there is not a single place in our neighbourhood on the Mersey and Irwell watershed where a very great degree of benefit cannot be practically brought about if the sanitary and urban authorities would undertake to do it.

3757. Yes. That is hardly my question. Is there any sewage effluent in the Mersey and Irwell watershed that by reasonable and practicable means cannot be brought up to your limit of impurity?—No, I know of no case in which by proper means, subsidence and filtration, the limit cannot be reached.

3758. In one or two instances the authorities have objected that they could not reach the standard, but on their being taken into court they have not fought the case out?—They have never been able to prove that they could not do it, and we have always been able to show that it can be done and that they can do it.

3759. Most authorities can turn out a better effluent than that demanded by your limit of impurity?—Yes.

3760. But we are not at present enforcing a better effluent?—No, I think we have acted most leniently towards them.

3761. Very well. Then with regard to manufacturers. they are protected in the same way by only being called upon to turn out the best practicable and reasonably available means, and they are further protected by an appeal to the Local Government Board, who are asked to consider the state of the trade in the neighbourhood?—That is so.

3762. Therefore the manufacturers are thoroughly protected?—I think so, and we have never really had any serious complaint.

3763. And the amount of purification we ask from them has really in the majority of cases been much less than the reasonable practicable and available means?—Yes.

3764. Therefore if standards were introduced up to the full force of the Act we should be asking polluters for more than we are now asking?—Yes, if the standard was fixed high.

3765. We will say the recommendation of the Commission of 1868?—Oh, certainly, yes.

3766. We should be asking for much more than we are now asking?—Certainly.

3767. And the result of that would be, as far as our experience goes, that we should get nothing done?—I think it very probable. I think the only reason that we have succeeded so well is that our demands have not been otherwise than reasonable and practicable.

3768. And the reason of the failure of the Act of 1876 has not been any difficulty about standards or about the best practicable means, but it has been the reluctance of the authorities to put the Act into force?—That is really the truth.

3769. And that reluctance has been from several causes, one the difficulty of proving pollution within their own borders, and another the feeling that one district might purify and another not?—That is also true.

3770. Then the non-enforcement of the 1876 Act does not turn in any way upon the question of standards or upon the question of reasonably practicable and available means?—No, that is my opinion; your statement is perfectly correct.

3771. (*Colonel Harding.*) Sir Henry, your experience in artificial filtration has been strictly limited to thoroughly settled sewage?—That is the case.

3772. I think you told us that the matters in suspension as you received them on to the filters did not exceed very much 1½ grains per gallon?—Yes.

3773. They have recently made up for a diminution in water capacity by filling more frequently?—Yes, they have.

3774. Have they formed any definite opinion as to the best length of time for contact with the filter?—Well, the result seems to be that they can afford to put

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on four fillings in the twenty-four hours, whereas we only put on three.

3775. Quite so, but in doing that do they reduce the time of standing empty or do they reduce the time of standing full?—They reduce the time of standing empty; they reduce the time of aeration.

3776. Then they do not reduce the time of contact with the sewage filter?—No; it was the time of aeration which they reduced.

3777. Then have they been able to come to any definite conclusion as to the best time of contact? Have they varied their experience?—That I do not undertake to say; I do not really know. As far as my experiments are concerned I found that the best result was when they were resting full, 20 per cent., and when they were aerating 60 per cent.; that is what I found to answer best; but that as far as the contact was concerned one hour's contact was sufficient.

3778. Then I must take it, Sir Henry, that you have no personal experience of experiments of longer and shorter contact?—No. I have made the experiments which I have stated here, namely, that we found the best thing we could do was to aerate for 60 per cent. and allow it to rest full for 20 per cent., but, as I have said, one hour's contact gave us purification, so that we were probably in excess of the time of resting; and as it appears from the experiments which have been subsequently made that they were able to put on four fillings while we only worked with three.

3779. Reducing only the period of aeration?—Yes.

3780. (*Professor Foster.*) But I think you said just now it was taken out of the time of aeration, and did not affect the time of contact?—Yes, the contact is the same and the time of aeration, as I think I said, was diminished.

3781. Might I just put in this question. Have you made any observation there in which you allowed the contact to be less than usual, and found that accompanied by inferiority in your filtrate?—We found that one hour contact was sufficient; that the difference between one hour's contact and two hours' contact was inappreciable

3782. Have you tried half an hour or three-quarters of an hour? The filtrate is as good after one hour as it is after two hours?—Yes.

3783. (*Colonel Harding.*) Then have you tried an experiment of this kind: When the filter is full to continue the flow for some time, in which case of course the time of contact would be somewhat reduced?—Of course, if you continue the flow up to a certain point you get a good result, but when you go on beyond a certain point, then of course the filter begins to be clogged, and begins to want aeration. You get the anaërobic forms coming into existence, and you do not get the aërobic ones, so that you must after a certain time bring in the air.

3784. But you have not formed an opinion as to the certain time?—That would depend upon the nature of the effluent, the nature of the sewage, and upon the construction of the filter.

3785. Then just two questions I want to put to you, Sir Henry. One is in regard to the value of tests for nitrates in an effluent. Do I understand you to say that in your opinion testing for nitrates was of no value because in some cases you had found that considerable purification in the filter had reduced the amount of nitrates?—I do not think I went so far as to say that they were of no value. I said I did not consider them to be of essential value as some do. I have here before me a statement which I think occurs in a report of Mr. Dibdin, in which he finds a perfectly astounding quantity of nitrates in the filtrate, both in the tank effluent and in the filtrate, and no doubt cases of that sort do occur, but, as I stated, the effluent from the filters which I have chiefly worked with do not, as a rule, show nitrates at all, and it is only when they have been standing some time exposed to the air, and when the first flow of water comes on, it is only then that we can even detect nitrates as a rule.

3786. Would the presence of iron liquor in a sewage affect the amount of nitrates in an effluent?—I do not know that it would. The presence of iron may affect the oxygen determinations. Of course if the iron be present in the state of ferrous salt, then the oxygen result will be perfectly wrong, but we never found a sewage that does contain an amount of iron that will affect the result. But I do not think that the presence of iron salts will affect nitrification, for where we have used iron as a precipitant we have found that the quantity of nitrates was about the same as it was when we used other precipitants, such as alum.

3787. You were asked, I think, by Professors Ramsay and Foster something about the possibility of differentiating as to the kinds and conditions of organic matter in an effluent. Do you know any test by which you could differentiate between living and dead matter in an effluent?—Not more than those I have stated, except bacteriologically, of course.

3788. (*Chairman.*) There is only one question that I wanted to ask you, and that was about your experiments at Huddersfield and Pendlebury. Those I understand are being conducted without using precipitations at all?—Well, we are making some experiments at Huddersfield with the view of seeing how far it is possible to deal with the sewage as it comes from the sewer upon contact filter beds.

3789. Without any precipitation?—Without any precipitation at all; it is a mere experiment for the purpose of getting to know something about it, but as I think I mentioned I do not feel at all able to give you a distinct opinion upon the subject, as we have not got our results sufficiently elaborated. At the present it has not gone on for a sufficient length of time. You see what may answer very well with a fresh filter may not answer at all with a filter that has been at work for a twelvemonth, and it is no use considering a method of treatment which is not of a permanent character. Although you may put the crude sewage on to a filter, and get excellent results for a certain length of time, it has happened over and over again in the case of patented filters, and patented material, that although they show a very excellent result in the first few months after a while they become absolutely useless; the whole thing gets plugged up, and you cannot get the liquid through. It has constantly been the case, and many of these processes which have been vaunted very much as being excellent, and are no doubt excellent to begin with; but the question is, what is their length of life? How long will they last, and therefore I should prefer not to give you any details upon that subject for a while, but after a time I hope perhaps, if you wish, to come and state the results of these experiments.

3790. How long have those experiments been going on?—About six months. It is not long enough. That does not apply to the question of the experiments as regards filtration from a tank effluent. What I have said now only applies to the question of fresh sewage brought on to a filter. About that I do not intend to give an opinion as to the question of whether the sewage can be permanently treated when the solids are not deposited either by mere subsidence or by additional chemical treatment, and brought on to a filter as crude sewage. There I feel that we have not evidence enough to say that it may be done.

3791. Are you prepared to say that a tank effluent can be satisfactorily dealt with by some system of artificial filtration?—Yes, I am. And I should like in reference to that, Lord Iddesleigh, to point out that in 1896 I recommended to the Corporation of Manchester that an artificial filtration area of filter beds composed of cinders should be carried out, which, under skilful management, ought to be able to deal with about 800,000 gallons of tank effluent per acre per day, the depth of filter material to be three feet and the construction of them to be the same as the experimental cinder filter about which I have spoken, it being of course understood that the present area arranged for land filtration shall be continued. I therefore, in 1895—even in 1895 so confident was I that this system of filtration through cinders after subsidence or chemical treatment would be effective that I advised the Manchester Corporation to spend £30,000 in putting down four acres of such filter beds. They did not take my advice; they will have to do it now, but they might have done it, if I might be allowed to say so, if they had followed my recommendations now four years ago, they would in that case have had evidence to bring before you which would have been, I venture to think, satisfactory. They would have been able to show that they had had thirty acres of filter beds of this kind in action for four years, and they would have been able to show you what the result of that action up to the present moment had been. They did not choose to do that, and the consequence is that I am at the present time unable to bring before you any statement of large filter areas as I should have been able to if that recommendation had been followed out.

3792. You are not aware of any large artificial filter area that is in existence?—None which is really satisfactorily working. At Huddersfield they had put up some years ago a very elaborate and expensive plant; a considerable area is covered by filter beds, but they cannot get any quantity of effluent out of them. They are all choked up, and the consequence is they do not get their effluent through. That was a particular form of filtration which as I have said before answered very well for the first few months, but after a time proved to be perfectly inefficient.

3793. But then what is the artificial filter bed made of?—That is what is known as a substance called polarite.

3794. (*Professor Ramsay.*) What is polarite, Sir Henry?—Well, it is very difficult to tell you what it is, because they have changed it about from one thing to another. It is all called polarite whatever it is they put in, but it is supposed to be an iron oxide; magnetic oxide sometimes they use, and sometimes something quite different.

3795. They have another material called magnetite; is that another thing?—That is the same thing, I believe. *Sir H. Roscoe, F.R.S., D.C.L., LL.D.* 17 Jan. 1899.

3796. (*Sir Richard Thorne.*) What is the new material used in the new filtering bed at Huddersfield?—Cinders.

3797. (*Major-General Carey.*) The result of your experiments is that cinders are a better filtering material than coke?—I am rather inclined to think so.

FOURTEENTH DAY

Wednesday, 18th January, 1899.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

Mr. WILLIAM JOSEPH DIBDIN, F.I.C., F.C.S., etc., recalled; and further Examined.

3798. (*Chairman.*) There are only one or two questions I wanted to ask you, and then Professor Ramsay will conduct the cross-examination. May I ask whether you in your system provide a screen of any sort for the sludge?—Oh, yes, I think it very desirable that a screen should be provided to catch the coarser and larger particles in the sewage, such as rags, and so on.

3798*. Have you had any actual experience of your filter in severe frost, when it might be frozen?—Oh, yes, that was carried through in the winter of four years ago, when we had the severest frost of the century, and the beds at Barking had then been working for something like two years, and during the whole of that frost they worked most successfully and satisfactorily. At the same time, similar beds were at work at Sutton, so that we had the double experience.

3799. And the beds themselves did not freeze?—No, there was merely a little thin film of ice where the water had stood just a little above the surface: but the frost did not get into the bed.

3800. And do you think the frost never would get into the bed?—Well, I can only speak of the experience we have had. That was the severest winter of the century, and it was a prolonged frost of about six weeks.

3801. Then with regard to storm water, do you allow all that to go through that filter?—Yes. I have been making special experiments upon that point, and I have prepared a table giving the actual quantity of work done, and the results of the analyses of the effluent both of the storm water and also of the effluent afforded by the beds after the beds have returned to their normal working of intermittently treating crude sewage, and, with your permission, I propose to put this in. Would it be your pleasure that I should just shortly glance through the salient features of the table?

3802. Yes, I think that would be advantageous?—Well, I have the experiments at two places; one is Worcester Park, the works of the Cheam and Cuddington Sewage Disposal system, which were only recently constructed. In consequence of the intolerable nuisance obtaining at these works last summer, double beds—coarse and fine—were put down at once, as the matter was urgent. The total cost has been something less than £400. The quantity of storm water coming off that district was very large, so much so that it was estimated that the water passing through only two pairs of the seven pairs of beds provided, in about eight hours, was equal to 200,000 gallons, or at a rate of 2,100,000 gallons per day, by a plant designed for treating only 80,000 gallons of normal sewage. The result showed a purification on the average of that whole period of 65 per cent.; that is to say, 66 by the albuminoid ammonia test, and 64 by the oxygen absorbed, with a total removal of matters in suspension. On the last of the effluents, that is at the end of the eight hours, the purification was 75 and 71 per cent. respectively, and those were with comparatively new beds. But I had a similar experience with the old-established beds at Sutton, and on November 27th the storm water was streamed on to Nos. 2 and 3 beds. I may explain what I mean by streaming. That is, the beds are then worked in the same manner as that in which a water company works its filters. The water stands on the top of the beds, or just level with the top, and it is allowed to flow out only at the rate at which it flows in, so that there is no special rush of water downward through the material of the bed; otherwise it would act merely as a sieve, and you would get no quiet sedimentation taking place. But where the whole body of the bed is allowed to come into play by the water slowly finding its way down from the top to the bottom, and into the under-drains, you then get the maximum effect of the beds used in this case as ordinary filters, the sewage matters deposited in them being destroyed in the course of time by the bacterial action, so that streaming means working the beds as water companies work their filters with water standing on the top, and only draining away as fast as you put it on. The quantity of sewage and storm water placed upon these beds during the nine hours—the duration of that storm was nine hours—was 104,160 gallons per bed, equal to 208,320 gallons for the two, and the purification per cent. by the albuminoid ammonia was 72 per cent., by the oxygen absorbed 63 per cent. on the last of the flow. On the average of the flow it was 29 and 27, showing that in this particular case we did not get quite as good a result as we have in others. But at all events, take it as storm water, a purification of about 30 per cent., plus the removal of the whole of the suspended matters, I think, must not be taken as a bad result. Then, on November 28th, the experiment lasted from 7.30 a.m. to 1.50 a.m.; the Nos. 2 and 3 beds were used, and in nine hours and forty-five minutes each bed treated 161,460 gallons, so that these two treated 323,000 nearly. The purification on the average of the whole period was 59 and 63 per cent. by the albuminoid ammonia and oxygen absorbed respectively, and during the last hour of the flow the purification was 81 and 71 respectively. On December 7th, from 2 to 8 p.m., similar experiments were made on Nos. 2 and 3 beds, and during the twelve hours each bed passed 198,720 gallons. The purification was 58 and 55 per cent. respectively, and during the last hour was 63 and 64. After December 7th the beds returned to their normal intermittent working as usual, and on December 9th, at 8.5 a.m., samples were taken—of course, care being taken that the samples of the effluent corresponded with those of the sewage. For instance, the sewage was sampled at 8.5 a.m., the coarse bed effluent at 11.30 p.m., and the fine bed effluent at 2 p.m., so that the final effluent would correspond with the crude sewage, and the purification shown by the albuminoid ammonia is 83 per cent., and by the oxygen absorbed 77 per cent. Summing up these various points, we have an average purification of the storm water by the oxygen absorbed factor of 54 per cent., and by the albuminoid ammonia of 53 per cent., plus suspended matter 100 per cent. After doing this work, the beds on return to intermittent working gave a purification of 77 per cent. and 83 per cent. respectively, and of "suspended matters" 100 per cent. That experience, I venture to think, will be of interest to the Commission as showing what the beds are capable of doing in the case of storm water. It is not the first time that the beds have been worked in this way, but it is the first time on which such very careful examinations have been made with regard to the quantity and quality. I have to thank General Carey for kindly suggesting to me the great importance of this point, and in accordance with his suggestion I have prepared this table for the information of the Commission. *Mr. W. J. Dibdin, F.I.C., F.C.S.* 18 Jan. 1899.

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TABLE OF RESULTS OF ANALYSES OF WORCESTER PARK.

STORM WATER "STREAMING" THROUGH BEDS.

Quantities stated in Grains per Gallon, except

DATE OF COLLECTION.	SEWAGE AND STORM WATER.												COARSE BED							
					Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Suspended Matters.		Dissolved Solids.						Ammonia.		Oxygen absorbed from Permanganate at 80° F.	
	Appearance.	Odour.	Reaction.	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.	Total.	Volatile.	Total.	Volatile.	Appearance.	Odour.	Reaction.	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.
1898: 26 November - "Streaming" through during eight hours.	T	S	F Alk	5·8	1·75	0·23	0·23	1·92	24·4	19·2	60·4	–	–	–	–	–	–	–	–	–

REMARKS.—Estimated Quantity 200,000 gallons, through two (2) pairs of beds out of seven (7) pairs = 700,000 gallons

SUTTON, SURREY.

1898: 27 November - 4.0 to 10.0 p.m.	T	S	F Alk	11·2	4·2	0·41	0·56	3·10	14·2	11·3	82·8	–	Average of No. 2 Bed,							
													T	S	F Alk	11·5	4·37	0·40	0·51	2·86
													No. 2 Bed, 10.15 to 11.0 p.m							
													C & B	Nil	F Alk	8·6	2·73	0·12	0·23	1·02

REMARKS.—Quantity "streamed" through No. 2 Coarse Bed in seven hours = 104,160 gallons. Quantity "streamed"

28 November - 7.30 p.m. to 1.50 a.m.	T	S	V F Alk	5·8	3·15	0·37	0·56	3·33	5·1	4·8	66·1	–	Average of Nos. 2 and 3 Beds,							
													T	S	V F Alk	6·6	2·94	0·17	0·33	1·40
													Same Beds, Last Flow,							
													T	W S	V F Alk	7·0	2·35	0·13	0·22	0·83

REMARKS.—Quantity "streamed" through No. 2 Coarse Bed in nine hours and forty-five minutes (9.45 hours) = 161,460 gallons. Quantity

7 December - 2.0 to 8.0 p.m.	T	S	V S Alk	7·1	1·57	0·19	0·44	2·41	11·1	5·4	82·6	–	Average of No. 2 Bed,							
													T	W S	V F Alk	6·7	1·12	0·17	0·11	1·97
													Same Bed, Last Flow,							
													T	W S	V F Alk	6·1	2·10	0·10	0·11	1·20

REMARKS.—Quantity "streamed" through No. 2 Coarse Bed in twelve (12) hours = 198,720 gallons. Quantity

9 December - 8.5 a.m.	T	S	V F Alk	7·4	3·25	0·364	0 54	0·32	19·4	17·4	79·9	–	No. 2 Bed. Bed worked intermittently after having							
													T	W S	V F Alk	6·5	2·46	0·147	0	1·40

GENERAL REMARKS.—The average purification of the storm water on "Oxygen absorbed" factor was, therefore,
After doing this work the Beds on return to Intermittent working gave a purification of

ABBREVIATIONS.—C & B—Clear and bright. F Alk—Faintly alkaline. S—Sewage.

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SAMPLES OF SEWAGE AND EFFLUENTS FROM—

WORCESTER PARK.

Storm Water "Streaming" through Beds.

Organic C. and N., which are stated in parts per 100,000.

EFFLUENT.						FINE BED EFFLUENT.															
Nitrogen as		Suspended Matters.		Dissolved Solids.						Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Organic Elements.		Nitrogen as		Suspended Matters.		Dissolved Solids.	
Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.	Appearance.	Odour.	Reaction.	Chlorine.	Free.	Albuminoid.	At once.	In Four Hours.	Carbon.	Nitrogen.	Nitrites.	Nitrates.	Total.	Volatile.	Total.	Volatile.
						Average of Nos. 1 and 2 Beds Effluents.															
–	–	–	–	–	–	T	Nil	F Alk	4·2	0·69	0·08	0·23	0·68	–	–	Slt Tr	0·623	Trace		61·1	–
Purification per cent.				–	–	–	–	–	–	–	66	–	64	–	–	–	–	–	–	–	–
						Just before finish of Eight Hours "Streaming."															
						C & B	Nil	F Alk	4·0	0·45	0·067	0	0·56	1·11	0·125	Nil	0·613	Nil		56·0	–
Purification per cent.				–	–	–	–	–	–	–	75	–	71	–	–	–	–	–	–	–	–

for all beds in eight (8) hours, or at rate of 2,100,000 gallons per day by plant designed for 80,000 gallons of normal sewage daily.

SUTTON, SURREY.

4.15 to 10.0 p.m.						Average of Nos. 1 and 2 Beds, 4.15 to 10.15 p.m.															
Nil		Trace		80·8	–	T	W S	F Alk	10·6	2·62	0·29	0·23	2·25	3·21	1·46	0·122	Nil	Trace		77·2	–
Purification per cent.				–	–	–	–	–	–	–	29	–	27	–	–	–	–	–	–	–	–
Last Flow.						Nos. 1 and 2 Beds, 10.15 to 11.15 p.m. Last Flow.															
0·028	0·335	Trace		79·5	–	C & B	Nil	F Alk	8·6	3·89	0·11	0·11	1·13	2·23	1·62	0·021	Nil	Nil		70·6	–
Purification per cent.				–	–	–	–	–	–	–	73	–	63	–	–	–	–	–	–	–	–

through No. 3 Coarse Bed in seven hours = 104,160 gallons. Duration of storm nine (9) hours.

7.45 p.m. to 1.0 a.m.						Average of Nos. 1, 2 and 3 Beds, 7.45 p.m. to 1.50 a.m.															
Trace	Nil	Trace		57·3	–	C & B	Nil	V F Alk	7·0	2·10	0·15	0·17	1·22	–	–	0·158	Nil	Trace		57·2	–
Purification per cent.				–	–	–	–	–	–	–	59	–	63	–	–	–	–	–	–	–	–
1.45 a.m. to 2.30 a.m.						Same Beds, Last Flow, 1.45 a.m. to 2.50 a.m.															
Nil		Trace		57·6	–	C & B	Nil	V F Alk	7·1	1·99	0·07	0·06	1·00	–	–	0·158	Nil	Trace		59·0	–
Purification per cent.				–	–	–	–	–	–	–	81	–	71	–	–	–	–	–	–	–	–

"streamed" through No. 3 Coarse Bed in nine hours and forty-five minutes (9.45 hours) = 161,460 gallons. Duration of storm, eleven (11) hours.

2.30 to 8.0 p.m.						Average of Nos. 1 and 2 Beds, 3.0 to 8.0 p.m.															
0·70	0	Trace		69·6	–	C & B	Nil	V F Alk	5·9	0·84	0·06	0·11	0·98	2·03	0·18	0·175	0·791	Trace		78·9	–
Purification per cent.				–	–	–	–	–	–	–	58	–	55	–	–	–	–	–	–	–	–
8.0 to 8.50 p.m.						Same Beds, Last Flow, 8.0 to 9.10 p.m.															
0·315	0	Trace		65·6	–	C & B	Nil	V F Alk	6·6	1·05	0·07	0	0·87	1·29	0·15	0·14	1·036	Trace		72·7	–
Purification per cent.				–	–	–	–	–	–	–	63	–	64	–	–	–	–	–	–	–	–

"streamed" through No. 3 Coarse Bed in twelve (12) hours = 198,720 gallons. Duration of storm, twelve (12) hours.

been worked constantly, 11.30 a.m.						Nos. 1 and 2 Beds. Beds worked intermittently after having been worked constantly, 2.0 p.m.															
0·49	0	Trace		74·0	–	C & B	Nil	V F Alk	6·1	5·25	0·061	0	0·70	1·11	0·16	Tr	1·274	Nil		83·5	–
Purification per cent.				–	–	–	–	–	–	–	83	–	77	–	–	–	–	–	–	–	–

54 per cent; Albuminoid Ammonia, 53 per cent.; and by the Suspended Matters 100 per cent.
77 per cent. and 83 per cent. respectively, and of "Suspended Matters" 100 per cent.

Slt Tr—Slight trace. T—Turbid. Tr—Trace. V F Alk—Very faintly alkaline. W S—Weak sewage.

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3803. Then, practically, you allow the whole of the storm water to go over the whole of the filters?—Yes.

3804. And you do not find the filter the worse for it?—No, the point being—you should clearly have that in mind—that, although you put more water through the beds, you do not put more sewage. It is the amount of organic matter to be destroyed, and not the mere quantity of water; in fact, the more water that it is dissolved in the better it will be. Perhaps, sir, it might save time if I put in one other table, which I think would be of some use, and that is a very full statement of the actual capacities of the beds from time to time; not only their actual water capacity, but I have also calculated out what would be the working capacities of the bed per acre, on the assumption that it may be filled once, twice, or thrice a day. Then I give the period during which the beds have been at work—the total number of days—and the times which they have been filled, the average rate of filling, and the total days which they have rested empty, and the percentage. Then I have also some interesting facts as to the average water capacity of the beds, on the assumption that they are one-acre beds, because one acre is a very good unit to take, and the total sewage treated—the average quantity treated per acre per day, including rest periods, and the total work done. Shall I just run through some of the conclusions of this, or shall I hand the table in?

3805. Perhaps you will hand the table in?—It will save time. I may point out that, as an actual fact, the average per acre per day treated on all the beds is equal to 721,059

SUTTON (SURREY) SEWAGE WORKS.

Coarse Grain Beds.

Capacity of.

Date of Measurement of Water Capacity.	Area.	Depth.	Cubic Capacity in Cubic Feet.			Percentage.		Working Capacity in Gallons per Acre per Day. Fillings Daily.		
			Water.	Filtering Material.	Total.	Water.	Filtering Material.	1.	2.	3.
	Sup. Yds.	Ft. Ins.								
No. 1 - -	–	–	–	–	–	–	–	–	–	–
August 22nd, 1897 -	186	5 3	2,796	6,011	8,807	32	68	457,378	914,756	1,372,134
October 6th, 1898 -	–	–	1,054	7,753	8,807	12	88	171,518	342,036	514,554
November 27th, 1898	–	–	1,132	7,675	8,807	13	87	185,811	371,622	557,433
*December 5th, 1898	–	–	1,528	7,279	8,807	17½	82½	250,129	500,258	750,487
January 11th, 1899 -	–	–	1,246	7,561	8,807	14	86	200,104	400,208	600,312
No. 2 - -	–	–	–	–	–	–	–	–	–	–
June 3rd, 1897 -	186	5 3	2,480	6,327	8,807	72	28	400,206	800,412	1,200,618
October 13th, 1898 -	–	–	1,213	7,594	8,807	86½	13½	192,957	385,914	578,871
November 30th, 1898	–	–	1,053	7,754	8,807	88	12	171,518	342,036	514,554
No. 3 - -	–	–	–	–	–	–	–	–	–	–
July 23rd, 1897 -	186	5 3	2,720	6,087	8,807	69	31	443,085	886,170	1,329,255
October 12th, 1898 -		–	1,496	7,311	8,807	83	17	242,983	485,966	728,949
December 3rd, 1898	–	–	1,475	7,332	8,807	83	17	242,983	485,966	728,949
January 7th, 1899 -	–	–	†1,643	7,164	8,807	81½	18½	264,422	528,844	793,266
No. 4 - -	–	–	–	–	–	–	–	–	–	–
April 30th, 1898 -	186	5 3	2,880	5,927	8,807	32¾	67¼	468,097	936,194	1,404,291
October 11th, 1898 -	–	–	2,261	6,546	8,807	25½	74½	364,473	728,946	1,093,419
December 5th, 1898	–	–	2,735	6,082	8,807	31	69	443,085	886,170	1,329,255
January 10th, 1899 -	–	–	2,570	6,237	8,807	29¼	70¾	418,072	836,144	1,254,216
Average - - - - - - - - - - - - -						21½	–	307,301	614,602	921,903

* After one week's rest.
† January 14th, 1899. After one week's rest, 2,098 cubic feet.

gallons. I am speaking of the coarse beds. The fine beds will do more. The total actually treated on all the beds is 91,000,000 gallons. Some of the beds have been at work two and a quarter years, and others only about nine months, but I think that will afford some valuable data for the Commission.

3806. (*Professor Ramsay.*) I suppose you would claim that the chief difference between your filters and others is that you allow the sewage to stay in contact with the filtering material for some time, and then run off, whereas in others it is run off at once?—Yes, decidedly. It is a distinct departure from the ordinary method of working in that the sewage is allowed to remain in contact with the beds for a certain period—two hours we have found to be a fair average.

3807. Do you think there is an advantage in that system over what one may call trickling through the beds?—We have found it so. In the case of No. 2 bed, that was constructed in the ordinary way of a stratified filter-bed, and we had a series of troughs across the top of the bed so as to distribute the sewage as much as we possibly could; and we ran the bed at different rates, and we had the same sewage side by side in the next tank with the simple unstratified bed, and we found that where

the unstratified bed continued to work satisfactorily the amount of work that we could get through a stratified bed and a slow constant trickling was very much less. It was so much so that they re-arranged the bed and went back to the ordinary No. 1 system as we call it.

3808. Then another advantage, which I suppose you would claim is that there is no special preparation in the way of mason work?—Many of the beds at Sutton—the first ones we put down—are simply holes in the clay with a sloping bottom, underdrains put in, and then the burned clay put back, or it may be stones or any convenient rough material of that kind and bricks or what not.

3809. Thereby there is a great saving of initial expense?—At Worcester Park there is an installation just completed at a cost, I cannot tell exactly what it will be, but it will be, I think, about £350 or £360 for treating 100,000 gallons of sewage a day.

3810. It is very much less than what would be if the mason work were required?—If the mason work were put in probably the cost would be £1,000 or £2,000, according to what was necessary, but it is simply a hole in the clay, that is all.

3811. Then, coming to the question of sludge, you do, I think, take off the large particles; you stop them with a grating, do you not?—At Sutton the quantity taken out of the sewage is twelve barrow-loads per day on 400,000 gallons of sewage. That you may take as being thirty barrow-loads per million gallons, and that is with a strong separate system sewage. With a weaker sewage

SUTTON (SURREY) SEWAGE WORKS.

Bed No. 1.—Original Coarse Bed.
2.—Mixed Fine and Coarse Bed, Stratified.
3.—Same as Original Coarse Bed.
4.—Ditto - - ditto.

Date when Bed started.	Number of Days to January 10th.	Number of Times Filled. Total to and including January 12th, 1899.	Number of Days Rested Empty to and including January 12th, 1899.		Observations.	
			Total.	%		
November 21st, 1896	780	1,723 Average per day = 2·2.	47	6·0		Gallons.
					Average water capacity per acre -	252,986
					Total sewage treated per acre -	436,000,000
					Average quantity treated per acre per day, including rest periods -	558,840
June 3rd, 1897 - (On intermittent system.)	587	1,259 Average per day = 2·1.	70	11·9		Gallons.
					Average water capacity per acre -	254,415
					Total sewage treated per acre -	320,000,000
					Average quantity treated per acre per day, including rest periods -	545,670
July 23rd, 1897 -	536	1,172 Average per day = 2·2.	63	11·7		Gallons.
					Average water capacity per acre -	298,726
					Total sewage treated per acre -	350,000,000
					Average quantity treated per acre per day, including rest periods -	653,184
April 30th, 1898 -	255	679 Average per day = 2·7.	17	6·7		Gallons.
					Average water capacity per acre -	423,075
					Total sewage treated per acre -	287,000,000
					Average quantity treated per acre per day, including rest periods -	1,126,540
					Average per acre per day actually treated on all beds - - -	Gallons. 721,059
					Total actually treated on all four (4) beds - - - - -	91,000,000

Considering No. 1 Bed only (which has been worked the longest and the hardest), since each gallon of the sewage contained 60 grains of "suspended matters," the sludge of 90 % moisture disposed of amounts to 7,800 tons per acre per annum, equal to an area of 1 acre covered to a depth of 6 feet.

containing surface and subsoil water, the quantity would be very much less, but as an absolute fact at Sutton it does average thirty barrow-loads per million gallons. That is so small that it hardly counts in the men's time; they simply wheel it away into a trench, cover it over, and use it in the garden for growing cabbages. It is buried there at once; there is no trouble with it.

3812. The filters dispose of all the other solid matter?—All the rest, without exception, has gone on to these beds and been treated.

3813. You find no appreciable blocking of the filters?—There is a variation according to the rate of work. This bed, bed No. 1, has been continuously at work with only 6 per cent. of the days at rest, since November 21, 1896. Call that two and a quarter years roughly. I have this footnote: "Considering No. 1 bed only (which has been worked the longest) since each gallon of the sewage contained 60 grains of 'suspended matters' the sludge of 90 per cent. moisture disposed of amounts to 7,800 tons per acre per annum, equal to an area of one acre covered to a depth of six feet." That is the work—the actual work—that has been done by that bed; the water capacity of the bed—the actual water capacity—is 200,000 gallons per acre per day. When it is filled at the rate of three

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fillings, as it very often is, that would give us a working capacity of 600,000 gallons per acre per day. And that bed, I may point out, has had exceptionally hard wear in consequence of something like 3,000 or 4,000 gentlemen visiting the works in the way of deputations, and most of them like to have the bed turned over and walk upon it. But at all events, it has had very hard work, and its working capacity now is 600,000 gallons per acre per day. The percentage water capacity or the bed has varied. It commenced with 32 per cent.; that is to say, it would hold 32 of water to 68 of the solid filter material, the 100 being the total capacity of the bed. It commenced November 21, 1896. On August 22, 1897, the water capacity was 32 per cent.; on October 6th, 1898, the water capacity—nearly two years after we had started—had fallen to 12 per cent.; on November 27, 1898, it had risen to 13 per cent.; on December 5, after a week's rest, it rose to 17½ per cent.; on January 11 it was 14. Similarly I have a statement for each of the other beds, the average of the whole being 21½ per cent. You see they vary from 32 to 12. Twelve was the lowest of those two beds. No. 2 should be put out of account, because, as I have marked it, it was a stratified bed, but No. 1 was the hardest worked, and still, after two and a-quarter years work, it is doing good work, and supposing, for the sake of argument, it was desired to increase the working capacity of that bed, we should simply have to lift out and put on one side the coarse material so as to separate it from the fine and throw out the fine material, and put a little more coarse in, and it would be a new bed. But as a matter of fact it is still giving excellent results; it is still in working order, and it shows that after over two years' work by a week's rest it rose from 13 to 17½ per cent., and if we had given it a longer rest it would have risen to its original capacity I have no doubt.

3814. Do you think so?—Oh, I have no doubt.

3815. Would it not be very desirable to prove that?—It would be very desirable, and we at Sutton are hoping to complete the installation with a view expressly to be able to put these beds out of work, but unfortunately our application for a loan is still in abeyance, and we are obliged to go on working those as hard as we can in order to satisfy the Thames Conservancy, because before we were not, and since we have had these beds we have been able to satisfy them, and we are obliged to go on driving these as hard as we can until we get our new beds ready, but as soon as we get our new beds ready then we shall be only too happy to place these entirely at the disposal of the Commission or ourselves to make any experiments the Commission suggest. I should like to put No. 1 bed out of account absolutely, and note the time that it did recover on the principle of a field lying fallow for a time, and I have not the slightest doubt of the result.

3816. The recovery, of course, would merely mean the removal of organic material, not inorganic material?—But I do not think we have much inorganic material in our case, because there is no road deposit to speak of.

3817. In three years?—It is a chalky soil; any chalk would be carried off by the carbonic acid. Road grit, cinders, and coal dust, and so on, you have to fear.

3818. That would not be the case everywhere; it may be so at Sutton?—At Sutton we have had no grit chamber; everything has gone on to the beds, but I am perfectly satisfied that it would be most desirable; in fact, in all places where I have the honour of being consulted, I advise that there should be an intercepting chamber to take coal, cinders, etc. In one case I found a considerable quantity of small coals coming down. I believe it arose from a coal washing machine being used, and the water discharging into the sewers. The road drift and the coarser sewage matters might easily be kept out by a grit chamber and screen, which would save the beds. But even supposing that at the end of four or five years it was necessary to resuscitate the beds it merely means separating the coarse from the fine, and throwing out the fine material and going on again with the beds in good condition.

3819. In the worst possible view, would it mean remaking the beds every three to five years?—The time is uncertain. It merely means rearranging the beds, nothing to do with the underdrains, sides, or excavations; it is merely going over the stuff with a fork like lifting potatoes out of the ground, throwing the fine stuff aside, and letting the coarse remain, so that the actual cost of doing this would be only 6d. a yard, and would not be a very material thing. But I may remind you, sir, that the expense of that would be largely mitigated if we had adopted a grit chamber and proper screens in this the first instance. Of course it was only an experimental thing. The preliminary grit chamber is now used in addition to the screen or combined with the screen. That in every case I think is desirable, as tending to increase the life of the beds and to keep their capacity up to a working rate—a full working rate.

3820. (*Professor Foster.*) You separate the small by screening—the fine from the large by screening?—Yes; or in filling a bed first of all we do not even take the trouble to screen it.

3821. I mean in renewing your bed?—In renewing our bed, yes.

3822. You speak of casting up the fine?—Well, they could do it by separating the coarse, by using wide-tined forks, as in filling a bed in the first instance we do not find it necessary to regularly screen it off. You have a heap of burnt ballast, and as the men work at that the coarse stuff rolls down and collects, separates from the fine, and they have merely to lift that by the fork, and they have the screening done mechanically; the fine is simply put aside.

3823. (*Professor Ramsay.*) I should like to ask you some questions as regards analytical problems, Mr. Dibdin, if you do not mind?—If you please.

3824. One as regards the oxygen-absorbed test; I notice that you take it at once—that is to say, the action of permanganate at once upon the sewage?—Yes.

3825. And then after being heated for four hours at 80° Fahr.?—Yes.

3826. Others take a different standard, taking it after some minutes, instead of at once, and let the temperature be the atmospheric one of 60° Fahr.?—Yes.

3827. The result is that you get different numbers expressing oxygen absorbed?—That is one of the inconveniences of the oxygen-absorbed method. The method I have employed for sewage work is, so far as the four hours is concerned, that employed by the Society of Public Analysts, but in the course of very prolonged experience in this question, I found there was no particular advantage in allowing sewage to stand for fifteen minutes; I mean, you get a different result, but no practical advantage is obtained by allowing it to stand fifteen minutes before completing the short period test. I allow the sample to take as much oxygen as it will take up in a few minutes until it holds the colour of the permanganate; it may be ten or fifteen minutes before you arrive at that point, putting it in slowly and carefully, but the actual period of fifteen minutes I found to be no advantage, and we use instead the term oxygen absorbed at once on the assumption that whatever oxygen is absorbed is taken up by matters such as ferrous salt, or something of that kind.

3828. But, of course, you would regard it as very much to be desired that different chemists should employ the same process in order to arrive at comparable results?—If this Commission will bring about such a result it will deserve the thanks of the profession I am sure.

3829. Do you regard the results as substantially differing from each other; I do not mean in amount, but in the conclusions you can draw from them. Supposing Mr. Scudder, for instance, takes the other plan of the fifteen minutes, and the four hours, and 60° Fahr., do you think that his final conclusions would differ from yours?—I do not think that the final conclusions in regard to the sewage question would differ in the slightest degree, but on individual samples you might have differences, but not ones of importance. For instance, the object of this test is to ascertain whether there were any matters in the sewage other than organic matter which would take up oxygen, and so tend to show that the true organic matter was greater than it really was; that is to say, if you had some salts like ferrous sulphate, then the short period test would indicate the amount of oxygen absorbed by that; then the difference between the short period test and the long period test would be the amount of oxygen absorbed by the organic matter, and my general experience inclines me to think that it is not a matter of moment whether the short period test is two, four, five, or ten minutes, or fifteen minutes; that is to say, you give it what it will practically take up at once. In the case of water, pure waters, drinking waters, the fifteen minutes is regularly adhered to for the sake of uniformity, but in the case of sewage work we have not found it necessary. Where you are doing a large amount of work, it entails considerable amount of extra work, and I saw no advantage.

3830. Then, to put it shortly, a sewage condemned

anyone using the other process would also be condemned by you?—Oh! clearly; certainly. You may take it with our test, that it extends over, sometimes five, six, or seven minutes, maybe more.

3831. Do your analyses relate to clear or filtered sewage, or to the sewage with sediment in it?—I have always held that water—it does not matter, sewage water or effluent—a sample of water, clean or dirty, should be examined with the view to ascertain the actual constituents in it, and to take solid particles of matter, and to state those in terms of oxygen absorbed, or of organic carbon, or nitrogen, or albuminoid ammonia, or what not, is really showing something which, although true in a way, is somewhat misleading to my mind. If you can say this sample contains so many grains of solid matter in suspension, and if you can differentiate what that is, all the better, you take that by itself for what it is worth, and you give a factor which people can understand. Then you take what is left, the matters in solution, and you say the matters in solution have such and such a character, and as near as we can possibly get to them we can say what they are; but to take the whole of your matters in suspension, churn them up with the matters in solution, and then to state the result in some factor which only the initiated can follow and understand the bearing of, seems to me to be an unnecessary complication, and moreover a very mistaken one, as it does not state as near as we can the actual character of the sample submitted to us. But if you say so much suspended matter, and you can divide it into organic and mineral matter, good; but as to the matters in solution, we cannot say what their actual constituents are, but we can only measure them inferentially by saying that on treatment in a retort with certain chemicals we get a certain result, or on heating them in a tube we get so much nitrogen or carbon, or submitting them to the action of permanganate so much oxygen absorbed, convenient factors, but not telling you actually what the actual quantity of organic matter or other matter is, and therefore I have always held, and in all my published analyses I have always separated suspended from the dissolved matters, and in that I believe I have the support of many of the heads of the profession.

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3832. But this plan of yours is not universal?—I am sorry to say it is not universal.

3833. It creates a great difficulty in comparison, does it not?—It is not universal. The system of including the suspended matters in an analysis of a sewage was introduced, I have reason for thinking, with a view to showing what a wonderfully high percentage of purification could be obtained by certain methods. In the old days of chemical precipitation it was a common thing to shake up the sample of sewage, to submit the whole thing with all the suspended matters to, we will say, the albuminoid ammonia test, split up the matters in suspension into matters in solution, as far as possible, and to estimate the total quantity of impurity obtained from them. Naturally, if that process were repeated upon an effluent obtained either by chemical precipitation by this, that, or the other process, or by a method of sedimentation, you would get a very high percentage of purification, and it was stated in some cases—I am speaking of years ago now—that this wonderful purification was effected by the marvellous agency of the chemicals put into the sewage, and it was used in my opinion as a misnomer, as a similar purification could be obtained, or nearly similar, merely by the process of sedimentation, and to claim for the benefit of certain chemicals that they could effect what you did naturally, all seemed to me to be an utter misnomer, and a wrong way of putting things, and that was one reason, amongst others, that I always object to including the suspended matters in the analyses of the matters in solution. I have here, sir, the results of a series of analyses which I have made on effluents both with and without the suspended matters.

TABLE OF RESULTS OF ANALYSIS OF SAMPLES OF FINE BED EFFLUENTS FROM SEWAGE DISPOSAL WORKS AT KNOSTROP, LEEDS.

Quantities stated in Grains per Gallon.

DATE OF COLLECTION.	FILTERED.				UNFILTERED.			
	Ammonia.		Oxygen absorbed from Permanganate at 80° F.		Ammonia.		Oxygen absorbed from Permanganate at 80° F.	
	Free.	Albuminoid.	At once.	In 4 hours.	Free.	Albuminoid.	At once.	In 4 hours.
1898:								
17 May	0·70	0·04	0·14	0·53	0·70	0·12	0·23	1·09
24 May	0·56	0·05	0·11	0·46	0·56	0·08	0·11	0·69
31 May	0·70	0·04	0·	0·57	0·70	0·11	0·06	0·98
3 June	0·56	0·05	0·06	0·74	0·56	0·07	0.11	1·09
7 June	0·70	0·05	0·	0·86	0·70	0·07	0·11	1·03
10 June	0·63	0·05	0·06	0·45	0·63	0·08	0·06	0·90
14 June	0·63	0·04	0·06	0·56	0·63	0·06	0·06	0·72
18 October	0·13	0·04	0·	0·46	0·21	0.05	0·	0·75
21 October	0·34	0·04	0·06	0·69	0·34	0·09	0·23	1·21
25 October	0·27	0·03	0·	0·34	0·29	0·08	0·17	0·80
28 October	0·42	0·03	0·	0·39	0·42	0·08	0·11	0·79
1 November	0·15	0·03	0·	0·42	0·17	0·07	0·07	0·84
4 November	0·21	0·04	0·	0·62	0·21	0·07	0·06	0·85
8 November	0·17	0·04	0·06	0·45	0·17	0·09	0·11	0·96
11 November	0·25	0·05	0·	0·51	0·25	0·07	0·11	0·90
15 November	0·25	0·03	0·	0·56	0·25	0·05	0·11	0·85
Average	0·41	0·04	0·02	0·54	0·42	—	0·08	0·90

With regard to sewage, if you take the whole of the suspended matters in a crude sewage, I am perfectly convinced that, by the ordinary methods of analysis generally adopted, the statements as to the totals representing the total quantity of impurity are utterly and entirely fallacious, because the processes did not split up the suspended matters, and you would fail to estimate the total quantity of impurity. There is only one method, I think, which could be relied upon to deal with the total matters in suspension, as well as those in solution, and that would be the organic carbon and nitrogen process, because there, whether the matter is in suspension or solution, you would get an absolute factor of so much carbon and so much nitrogen. But if you put solid matters into a retort, and boil them up, with the view of getting the total albuminoid ammonia, as it is called, from them, you would be disappointed. If you put solid matters into water, and treat that with permanganate under the impression that by measuring the quantity of permanganate destroyed you were going to estimate the total oxidisable power of the organic matters, you would be disappointed, and so on; and therefore I say the two things should be kept separate; and in regard to sewage it would be altogether misleading. But as the matters in suspension in a sewage effluent are of a different character entirely, you might get some more comparable results, and it might fairly be taken that you would have a difference in proportion to the amount of suspended matter, especially if the suspended matter is consisting largely of organisms. I have made a series of analyses

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with a view to showing what would be the difference if you include the suspended matters with the matters in solution; and I have this in two forms; I have it in tables. It is on the figure of albuminoid ammonia, and on the oxygen absorbed in permanganate at 80°, because if we did it on the carbon and nitrogen, it would have been a very lengthy process, and, for this particular purpose the question was not raised so far as carbon and nitrogen is concerned. There is no difference in the free ammonia; the average of the albuminoid ammonia in the unfiltered sample is ·08, whilst in the filtered sample it is ·04; and the oxygen absorbed in four hours on the unfiltered averages ·90, that in the filtered being ·57.

3834. Then to sum up, I take it that you perform analyses of the sewage and also of the effluent on the filtered material and not on the crude?—Yes.

3835. But you also state the amount of suspended matter?—The amount of suspended matter we state separately.

3836. Which is not estimated in any way separately. You merely take it as suspended matter without troubling about what it is?—Well, we generally give it as the total amount of mineral and of matters volatile at a red heat, and if there was anything specific in it then of course that would be stated.

3837. You do not estimate total nitrogen, I suppose, by Kjeldahl's process?—Sometimes, but I prefer the combustion process—Frankland's.

3838. But you do not state total nitrogen, I think, in your analyses. I had difficulty in interpreting them. You give nitrogen as albuminoid, ammonia as nitrites and nitrates, and then total nitrogen. Does that refer to the sum of those merely, or have you estimated them specially?—I do not think I have stated total nitrogen, have I?

3839. May I just refer to page 165, to the table; it will serve as well as any other. You give free ammonia and albuminoid ammonia?—I rather avoided that point of total nitrogen, because unless you gave the organic nitrogen by the combustion process or Kjeldahl's, the albuminoid ammonia does not give you the total; it is only partial.

3840. I do not think there is total nitrogen mentioned?—I have rather avoided that, sir, as the organic nitrogen was not estimated.

3841. Do you think it advisable to estimate total nitrogen?—I must confess that I like it, and, moreover, in doing it by the organic carbon and nitrogen process you get another factor which none of these ordinary ones take notice of, and that is the organic carbon. I must say I have used it very largely in my official work, and I use it now in my private work, and I prefer to use it.

3842. That is Frankland's process?—Yes; Frankland's process.

3843. Then, to pass to a point of detail, do you estimate the nitrates after the water has been distilled with caustic potash or not?—In some cases, but where there is nothing to interfere with the reaction we often use the indigo process, but I like to use the alumina foil process as a check; that is the one I stand by. Whenever I am in doubt we always go back to that, but for general purposes the indigo process answers very well.

3844. It is sufficiently accurate?—But we always confirm by the alumina foil process. The copper-zinc couple-method for clean waters is a very good method.

3845. Have you made any attempts whatever to differentiate the various compounds containing carbon, nitrogen, etc? There must be different classes of compounds which are put together as giving albuminoid ammonia?—Clearly; that is one of the points on which a great deal of work remains to be done.

3846. Have you made any attempt, or do you know of any attempt made to differentiate?—No; I have heard of attempts, but I have not heard of any successful ones.

3847. Do you think that standing in contact with permanganate of potash for known different times would give some estimate of the different kinds of material?—With regard to that I have myself made experiments upon the permanganate test, the oxygen absorbed, and that is one reason that I view it with a considerable amount of suspicion as a means of measuring the total quantity of organic matter. It is a measure rather of the organic matter in a certain condition; for instance, if you take a solution of cold fresh gelatine, you will find that the permanganate will have very little effect upon it, almost none; but you once let your gelatine undergo incipient putrefaction, once start the breaking down of the molecules, and the permanganate will attack it rapidly, almost as fast as you can put it in. Now, supposing you submit your solution of gelatine to the process, it depends entirely upon the condition in which your gelatine is. I have made that experiment myself, and I have done it over and over again with sewage. You can add permanganate to a sewage up to a certain point, and it will destroy the permanganate, it will become decolourised, you add some more, and presently you will arrive at a point when it will take no more, the colour of the permanganate will hold; but after a time, what we now know to be the bacterial action proceeds, the organic matters in the sewage will become amenable to the action of permanganate, and you can add a further quantity until you come to a dead stop again; it will take no more; allow the bacterial action to proceed further, you get further decomposition, and then you get your permanganate absorbed again, and you may go on with this with a sample of sewage for days. It is some years ago since I made these experiments, and I have made them in connection with the use of permanganate for the purpose of deodorising sewage. The contention was that it was perfectly useless to attempt to deodorise sewage by permanganate, because you might add such an enormous quantity and it would be taken up by non-putrefying matters, and possibly leaving the putrefying matters unaffected, that is to say, that if you take a volume of water the organic matters in the top, although not in a state of decomposition, would absorb the permanganate so rapidly that it would be all gone before the putrefying matters at the bottom of the vessel could be attacked; it is utterly fallacious, because we found that it was the matters in a state of putrefaction which were first attacked, and those that were not in a state of putrefaction were attacked at a later stage.

3848. I suppose you would agree that what we really wish to know is whether the effluent is capable of putrefaction or not?—That is the point, I take it, that a good effluent does not putrefy, and is one in which fish can freely thrive, that being so, we have an effluent good enough to turn into our ordinary rivers.

3849. Then do you consider what is called the oxygen absorbed test and the albuminoid ammonia test as bearing upon that question?—Yes, but unfortunately neither of them gives us a measure of the total quantity of organic matter. They are very convenient as differentiating one sample from another, but they are not so accurate.

3850. They are not accurate?—They are not accurate as measures of the organic matter.

3851. (*Professor Foster.*) Might I conclude from what you said that the oxygen absorption is not so much a measure of any albuminoid matter as of albuminoid matter in a particular condition?—That is so.

3852. (*Professor Ramsay.*) Then one more point. You know, I suppose, what has been termed the incubator test?—Yes.

3853. Do you regard that as of any value?—Well, I have not used it myself. I have generally found that the information could be obtained by the ordinary methods quite as well as that, although, as a matter of fact, if a sample does not putrefy at a certain temperature within a certain time you may take it that that is a very fair sample. I do not disagree with the test at all, but it is not an absolute one.

3854. It appears to me that there are two reasons why a sample may not putrefy, first, it may have already undergone such decomposition as it is capable of, or, second, it may not contain organisms enough to go on putrefying?—Clearly, that is so.

3855. Would it not be possible, do you think, to devise some test in which organisms were added to the effluent, and then it could be determined as to whether, under the most favourable circumstances, it would undergo decomposition?—Well, yes, I should say so, but it is a point. I should like to consider it. I see clearly it is a new application of the bacterial method.

3856. Precisely, for analysis?—I rather like the idea of it, but it is the first time I have heard it mentioned. It is very much on the lines of the experiments made by Dr. Dupré for the Local Government Board in 1882 and 1883; you know those?—Yes, I know that there are such, thank you.

3857. (*Professor Foster.*) Do I gather, Mr. Dibdin, that the changes which take place in your two kinds of bed, the coarse and the fine, are on the whole alike; that the difference between the two beds is that in the coarse beds you have larger channels, which therefore do not get so

easily blocked up?—That was the object for which the beds were made in that way, and to prevent as far as possible the anaërobic action, as, I believe, as a general principle, it is better to do the work by the aërobic rather than the anaërobic.

3858. You consider that in both beds the channels are aerobic?—Yes, to a great extent. Of course, I can quite conceive that in certain cases in the coarse bed they may be anaërobic, and, in fact, when they do that you get an evil-smelling effluent, you may get sulphides formed, and so on, and then we always say a bed should have a rest.

3859. You get actual solution of matter, do you not, in your coarse bed?—Oh, yes.

3860. And to a certain extent in your fine bed?—Any solid suspended organic matters placed on the fine bed are all destroyed and solutionised there.

3861. As a matter of practice, your effluent, your filtrate from the coarse bed, does not contain a large quantity of suspended matter?—At the first experiments at Barking, on the average of some years' work, we had about seven grains of suspended matter per gallon, and that was all arrested and destroyed by the fine bed. At Leeds, I think, there was about eleven grains. That was destroyed by the fine bed. At Sutton they were only 2·78 in the coarse bed effluent, and these were all destroyed on the fine beds.

3862. But in your coarse bed there is a very large consumption of solid matter?—You put on to the coarse bed the whole of the solid matters in the sewage, except perhaps a small quantity taken away by straining.

3863. Save those which have been screened off?—Yes.

3864. What is the mesh of your screen?—At Sutton now it is about a quarter of an inch. With regard to the actual work done, I may say that at Sutton, as I stated just now, the quantity of sludge destroyed per annum is equal to an acre of sludge six feet deep upon an acre of these beds. At Leeds it came to an acre of sludge four feet deep. It practically means this, that the beds will destroy in twelve months a volume of sludge equal to their own capacity.

3865. (*Professor Ramsay.*) May I ask what quantity of water?—Sludge. That is sludge of 90 per cent. moisture.

3866. (*Professor Foster.*) Have you made any observations without your screen?—Yes, at first.

3867. How large morsels will your coarse filter destroy?—I do not know precisely, but the interstices between the particles of coke would govern that. If they found their way into the bed they would be destroyed, but undoubtedly the greater the division of the particles, the more rapidly will the action take place, because it is a surface action; decrease the size and multiply the number, and you really multiply the surface, and consequently you get the work done in a shorter time; but if you have the particles larger than the spaces between the portions of the bed, then they accumulate upon the surface, and form a deposit, and, of course, there you lose the effect which would be produced by the division. Theoretically, the best thing to do would be to smash all the solid matters in the sewage into as fine a pulp as possible. That would be the best thing, because then you would get the action much more rapid.

3868. A good deal of that action in the fine bed may be described, I suppose, as a process of nitrification?—Oh, yes: of the nitrogenous matters, of course.

3869. As far as the nitrogenous matters are concerned?—Yes.

3870. But in your coarse bed there are changes in the nitrogenous matter leading, I suppose, to setting free of ammonia, which is subsequently nitrified?—Yes, but that varies with the season. Sometimes you get an increase of ammonia, but generally a marked decrease when the beds are working properly.

3871. Never mind, because my point was simply this, that, at all events, in your coarse filter you have processes going on leading to the formation of ammonia, and also to the nitrifying of ammonia, going on side by side?—Oh, yes, clearly; considerable nitrification, and if the coarse bed is made of chalk, you get a higher nitrification than you do with any other material, as much as ·8 grains of nitrogen as nitrates in a coarse bed made of chalk.

3872. In fact, you believe that in both your filters there is a number of changes, carried on by different organisms, going on at the same time?—That is so.

3873. Leading eventually to hardly anything more than carbonic di-oxide and nitrates?—That is the result of all my work.

3874. And the difference between your two beds is simply a difference of passages?—Purely. I do not believe there is any difference in the actual action which takes place at all; I believe it is merely that you must make it coarse, because you have to deal with coarse particles.

3875. You have not formed any ideas or acquired any knowledge as to the details of the changes, as, for instance, how the cellulose material is dissolved?—They are very slow. I have carried out a series of experiments, and I had hoped to have had the pleasure of putting them before the Commission, but they were not completed in time. Taking meat, a portion of muscular fibre—the lean of meat and a portion of fat—some wool, some cotton, and so on, I immersed these in beds, with the view of ascertaining the period they would require before they were each destroyed. In the case of the lean meat, it went in about three or four weeks—that is to say, a piece weighing about two ounces, a solid piece—went in about three or four weeks.

3876. That is, just driven down into your bed?—The bed was, say, half filled, then the piece of meat was put upon the surface of the coke, and then the coke put on to cover it up, so that it was really immersed in the middle of the bed.

3877. (*Professor Ramsay.*) Of an active bed; of a going bed?—Yes; and in about, I think it was, three or four weeks that had disappeared. It was examined from time to time; you could see it in a state of decomposition, and the whole thing was in a slimy state, and large numbers of micrococci feeding upon it.

3878. (*Professor Foster.*) Decomposition, putrefactive decomposition?—Well, it was hardly what you call in a putrid state; it was certainly an unpleasant odour, but I noticed it was a distinctly different odour to what we call putrid meat. It seemed as if the matters which would have become putrid as they were solutionised got washed away, and I have not the slightest doubt that if we had not supplied the bed with water in the usual way we should have had that in the usual very unpleasant state of decomposition. But it seemed to melt away in a slimy condition, and that was washed away, and when we examined the slime we found it was nearly all micrococci. In the case of the fat, I found the development of a large number of amœba, and the action was very slow, and, in fact, we have not got rid of it yet. The experiment had to be stopped for other work.

3879. How long did it last?—The fat lasted—I think it went on for over a couple of months. It was a large piece of fat, roughly speaking, an inch cube; and the cotton and the wool seemed to be most resistant. The wool was evidently being attacked; but as to the cotton there was softening, swelling up and general softening of the fibres, and there was a considerable number of bacteria attached to the fibres I noticed, but you could not say there was any material destruction had taken place in that time.

3880. Have you examined your filters for the presence of organisms other than the ordinary bacterial organisms?—Oh, yes, I have frequently examined them, and I found, especially in the warm weather—the summer time—large numbers of the lower infusoria that you generally find in pond water—very abundant.

3880*. Nematoid worms?—Yes, and very large numbers of larvæ of that little white fly, I do not know its name, that you often see in fields.

3881. That is on the surface?—No; I have found them right down, permeated into the substance of the bed. Samples of burnt ballast taken at some depths, some few feet depths below the surface, contained these organisms, and I found they were one of the most active agents in causing the bed to disintegrate—the particles of the bed to disintegrate—when it was made of burnt ballast, because you know the particles of burnt clay will have cracks in them in all directions, and these larvæ will travel into the cracks, and take up their abode there, and after a time the particle will soften, and easily come apart, and that is one reason that, although burnt clay may be very cheap at the start, it is a question whether in the long run it will be as cheap as, say, coke or flints, if flints will answer equally well, and I have found granite and slate to answer very well.

3882. Have you any reason to think that organisms, other than the so-called bacterial organisms, play an important part in the reduction of your material?—I should think a great proportion of the work is carried out entirely by the bacteria.

3883. Ninety-nine per cent.?—I should feel inclined to say so, as a result of general experience. You find them

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in the gelatinous form, and they are there right throughout the mass, while the others are only here or there.

3384. They do not occur in large masses, any of the large organisms?—No; but to some extent.

3385. In your filters?—No.

3386. I forget in your evidence now whether you spoke definitely and particularly in favour of any particular material?—No; it is merely the surface action. I have given in my evidence, grit, slate, granite, coke, chalk, and so on, and I hope soon to have an enlarged experiment at work on the coarse flints from the drift. There is a belt of drift runs through a sewage works, and in that case they are going to make their coarse beds with it. They have put down a pair of coarse beds with coke and breeze, and alongside a pair of coarse beds, which will be filled with the coarse flints from the drift, and the fine bed with the fine sand, the fine stuff in the drift, really dividing the drift practically into two, coarse and fine beds, and then we will have very definite experiments in the long run between the coke and the flint. If the flints prove to be equally efficacious in this particular case, it will save about 25 to 30 per cent. in the cost of the works, because they have got the material to hand.

3387. The question, I mean, of the kind of material does also make a difference in the surface, does it not; I mean to say, with pieces of flint you have only the space between the two pieces of flint; in the cinder you have the cavities in the cinder?—Yes, that is so, and that was the first reason that appealed to my mind so much in favour of burnt ballast, or clinker, or coke, or so on, but, after a time, you find that the surface of the coke in the body of the bed becomes covered with a deposit, and this deposit evidently seems, I am concluding, to do away with a good deal of the supposed advantage in the initial stages, the advantage of the irregular surface of the coke; that is to say, these interstices become filled up, and each particle of coke will probably not give you much more surface than a particle of flint.

3388. It has, so to speak, a shirt of bacteria?—That is it.

3389. (*Major-General Carey.*) With regard to the experiments with storm water, what portion of dilution have the volumes of sewage, which have been passed through the filters during the storm represent?—In nine hours in one case, we had, through two beds, and I believe these were the only two in use at the time; they took it all; we had 208,000 gallons in nine hours. That would be practically half as much as our daily flow of sewage, which is 400,000 gallons, so that in nine hours we had 200,000; consequently we should have had as much water down in eighteen hours as we should have got under normal conditions in twenty-four hours, so that the dilution there was not great. In the next case we had 320,000 in ten hours nearly, and judging by the chlorine the dilution had been about double, or equal volumes, roughly speaking, of storm water and sewage. In the case of the Worcester Park, well, it was enormous; we had in seven hours 200,000 gallons, the plant being designed for 80,000 gallons daily. I have worked it out, and find that it would have treated 2,100,000 gallons at this rate in the twenty-four hours.

3390. Where the sewage is diluted by twice its volume by the storm water, and treated in the filters, that is, on the coarse and fine beds, should not some separate provision be made in your provision for the treatment of storm water when the sewage dilution rose to five times?—It would be quite possible, of course, to have a separate storm water bed; it is merely a question of the area of the beds which may be found to be necessary. If one acre is insufficient, there is generally plenty of land to put up another acre. It is merely a question as to what may be considered the necessary area. Of course, we can only speak at present within the limits of the actual work done; I do not want to go beyond that; I do not want to support this by theory, but simply to submit facts to you.

3391. What do you consider to be the best period of rest for the ordinary sewage, when the filter is charged and after it is empty?—Well, with the fine beds we have worked them for years now; you may take it that they have been running altogether for about seven years, because it was 1892 when I first commenced these at Barking and Sutton. They will run very well with filling three times a day.

3392. In the twenty-four hours, do you mean?—In the twenty-four hours; that is to say, in three shifts of eight hours each, taking the time for filling, resting full, emptying, and resting empty.

3393. That would allow two hours in the filters, and four hours rest after the filter was empty?—Yes, that would be one hour to fill, two hours to stand full, one hour to empty, and four hours resting. Of course, it will vary with the rate of the flow of the sewage. It may take a little longer to fill, and a little longer to empty. Those are engineering details. You will get three to four hours rest every period of eight hours, which would give you practically twelve hours resting empty for aeration, but with the coarse beds the three fillings a day is too much. They will not stand three fillings a day continuously. In calculating on all new work, I take it as two fillings a day, and then I like to have a good margin upon that, because there is no doubt that the carbonaceous matters in sewage do take a longer time to go than the purely nitrogenous, and it is necessary, as you would in putting up a steam-engine of certain horse power, to provide a certain margin, and I think we may safely take a leaf out of the engineers' book in this matter.

3394. Would you say that four hours is the minimum period of rest for the filter when empty, in order to purify the sewage or produce a purified effluent?—For normal sewage, yes, I think, you might say so, but, of course, it will depend upon the kind of sewage. If the sewage is very diluted, as in some cases——

3395. I am referring to domestic sewage?—In purely domestic sewage at Sutton, then, you cannot go beyond three fillings a day. You may on emergency. I have done so five or six times a day, but you must give corresponding periods of rest.

3396. In all cases where domestic sewage is treated, you would allow the four hours' rest after the filter was empty?—As nearly as possible.

3397. And two hours full, when the filter was charged?—Yes. I think, in putting up a fresh installation, it would be advisable to allow more capacity than that necessary for two fillings daily at first working. Mr. Strachan, who has paid some attention to this, and has been kind enough to look into it very carefully, thinks it is wise to have a provision sufficient that you need only put the sewage upon the coarse beds once a day. Well, I think he is taking a very wide margin, much wider than I do, but still even then, he says, from an engineering point of view, that it is well worth it.

3398. Which is the more important rest in the filter, rest after it is empty for aeration?—Rest after it is empty, because if the effluent from the coarse bed is not quite up to the standard, the fine bed will act as a safeguard, and that will be all right.

3399. (*Professor Ramsay.*) Have the gases from the interior of the filter bed ever been analysed after the rest is nearly completed; is oxygen absorbed in great quantity by the organisms during the rest of the filter?—I think I can hardly answer that with safety. A good deal of work has to be done upon that point.

3900. Do you think it is likely?—The question of oxygen absorbed by the gelatinous matter in the filter is a very complex one, and I am not prepared with the results.

3901. It has really not been touched?—It has practically not been touched.

3902. (*Professor Foster.*) What do you think is taking place during this rest?—The continued action of the organisms.

3903. On the film left over them?—Yes.

3904. No more?—I do not think they stop; they do not stop; as long as that film is kept moist they will go on feeding, because you do not absolutely empty a bed; you do not absolutely drain away the last particles in it; there is a quantity of contained moisture on the surface, because a bed will go on draining for a long while. I think the bacterial action is simply continuously at work; it is only a question as to the quantity of sewage with which they can cope in a certain period.

3905. Is it your idea, then, that what takes place is this: that during the filling, I mean the material clings to the surface and the side passages, and during the period of resting the process of digestion which I may say had begun is carried on and completed?—Any particular particle is not destroyed in the bed during that period of two hours rest. I take it what is done during that period of two hours rest is that each cavity in the bed becomes really a settling chamber. The solid matters in the sewage by the action of gravity subside or adhere to the sides of the larger particles as chips of wood in water will to a boat, and that when you draw the water away from the bed those solid matters are left behind and the bacteria gradually extend over them, and in the course of time

they become solutionised, and as the outer surface goes into a state of solution the next flow of water comes in and washes that away, the work being gradually and finally finished in the fine bed.

3906. (*Major-General Carey.*) The periods of rest apply to the fine beds as well as the coarse?—Yes.

3907. The same periods of rest?—Well, the period that I gave you just now, the four hours, that is to say, three cycles of work of eight hours each, are upon the fine bed work, and those have worked at that rate now for seven years. The only question we have now is the best means of getting the maximum work out of the coarse beds.

3908. The water capacity, as I understand, may be estimated at one-third of the total cubic contents of the filter?—At the start.

3909. And what reduction of the capacity should be allowed for the matured beds?—Taking the average of these four beds that we have at Sutton, and which work very strong sewage and work very hard; the present capacity averages 21½ per cent. of the cubic contents of the tank.

3910. That would be about one-fifth of the total capacity, would it not?—Yes; but that is somewhat low, because No. 1 and No. 2 are exceptional, but at all events I do not want to do anything but take that absolute figure, which is at present 21½ per cent.

3911. Is that the figure that you, or the proportion that you would lay down as sufficient to provide in any scheme for the area of the beds?—I think you would have a very safe working margin there, but that would entirely depend upon the kind of sewage.

3912. At page 141 of your evidence you say:—"Leeds coarse bed, the original capacity is 174,813 gallons; liquid capacity, 83,330 gallons"?—That was the initial.

3913. But that is not one-third, but more like 50 per cent.?—No, because that bed was made with very coarse coke. The Sutton bed was made with stuff rejected by a half-inch mesh, and my experience with that bed led me to the conclusion that it would be very much better if the grain of the coarse bed was much larger, and therefore I advised that the coarse bed at Leeds should be made of very coarse coke, and that, of course, gives a very much larger initial water capacity.

3914. Then the reduction of the water capacity goes on to a very serious extent from the 1st of October, 1897, to the 8th of September, 1898?—Yes.

3915. In a much larger proportion than your 21 per cent.?—Oh, yes, but of course the reduction of this Leeds bed must be looked at in the light of the Leeds sewage. There the bed was worked during the greater part of the period with sewage screened only through a one-inch mesh, and, as explained, I have no doubt that you have the report of Colonel Harding upon these Leeds experiments, and there the facts are very clearly set out indeed, and the experience there confirms my own experience at Sutton and elsewhere with other sewages. With this peculiar sewage containing such a large quantity of iron, it is desirable that there should be some means of settling out and screening out the refuse of the stuff, the paper, ropes, rags, and all the road grit, and so on. It evidently is rather hard lines upon the beds to have to deal with all the matters that may go upon them with unscreened sewage. For instance, on the Leeds bed we found particles of coal, and of course they were quite exceptional. But what I have found with that Leeds bed is this, that the matters deposited upon the surface of the coke consist of about 85 per cent. water, about 7½ per cent. organic matter, and 7½ per cent. mineral matter, and of the mineral matter half is oxide of iron, so that we have really of that reduction in capacity only about 7 per cent. due to organic matter accumulated in the beds, and the fact that the capacity of the bed remained practically constant from the 27th of January, when it was 45,423, to the 2nd of October, when it was 46,890, does show that although it was receiving, with periods of rest, its daily increment of sewage, yet the capacity had not become reduced in that time. Since then—since these figures have been put in—I am informed by Colonel Harding that the capacity of the bed which is being worked now at the rate of three fillings a day, except on Sundays, has become still further reduced. How long it will be before the capacity will be so far reduced as to make it inadvisable to continue working the bed without sifting out the coarse stuff from the fine is a question for further experience. We can only tell by the results of actual working. I do not see how theory can help us in this matter. It is clear that if you put upon a bed so much organic matter in so much time, and the action of the bacteria is unable to cope with the daily increment, then you must have a rate at which the bed begins to fill up with the solid matters. And it is the object of such experiments as these to ascertain that point, and when we have ascertained that we shall have definite information, but, as I said before, I do not wish to go one step beyond the absolute facts. I have no object in trying to.

3916. Of course, on the other hand, we want to get the facts as far as possible, because schemes are coming to us for criticism, and unless we have the data it is almost impossible to criticise them?—I wish to help you, but still, if I begin to give you theories they will be no use, and we shall get into an atmosphere that will not be worth anything. There is this question of what is called the sludging up or the choking up of the sludge beds, and it is one which must be fairly met. I can only give you the facts that after the 2¼ years working with normal sewage the coarse bed is still doing good work. Its capacity has become reduced. How long it will be before that bed will be rendered useless I cannot tell you, but this is the satisfactory fact in my mind about it. We will take October 6th, 1898, when the No. 1 coarse bed at Sutton had a water capacity of 12 per cent., that is to say, after nearly two years work, and the argument would have been that in a very short time that bed would be rendered perfectly useless. Well, we continued working it, and it had a rest and its capacity went up to 17½, and if we can give it a prolonged rest we shall have its capacity still further increasing. In the case of No. 3 bed the capacity went down to 17 per cent. in October last, and in January, on the 7th, its capacity is 18½ per cent., its capacity having been remeasured on the 14th, is 24 per cent., and in the same way the capacity of No. 4 bed on April 30th was 32 per cent., and on January the 10th 29¼ per cent., having been down to 25½ in October. Now, it shows this, and if you take the same thing with the Leeds bed we have the same fluctuation after an initial reduction of from 83,000 to 45,000 on January the 27th. On the 6th of October it is only 46,000, or more in October than it was in January. Of course it has gone down since, and I should not be surprised if it went down a good deal more in the case of Leeds.

3917. But surely if it goes down at that rate, it will very soon become useless?—That is exactly the point: will it continue to go down at that rate? If we had argued on that at the Sutton beds originally, when they went down to twelve, we should have said in another month or two it will be perfectly useless, but in another month or two it was not perfectly useless. There is a sudden drop by reason of the accumulation of the organic matters on the bed, and then you come to what you may call your working mean, and that will go up and down, up and down, according to the periods of rest, the nature and the quantity of the sewage put upon it.

3918. But in this Leeds case, you gave it a rest of nearly a month, or more than a month?—Of three weeks.

3919. From the 16th of June to the 25th July?—Oh! yes; I beg your pardon.

3920. And even when you commenced, the rate was not nearly equal to your original starting rate, and fell between July and September from 56,000 to 40,000?—Clearly; and here is one of the points that makes it so desirable that the coarser solid matters, and grit, and so on, should be kept off the bed. The settled sewage was put on the bed on the 12th September, and then the capacity rose from 40,000 on the 8th of September, to 46,000 on the 12th, and on the 6th October to 46,800, so that if we had had a suitable grit chamber and screen during the whole of these experiments I do not think that the capacity would have shown anything like the reduction that it does at the present time; and when we look at the fact that about ten grains per gallon of organic matter went upon the fine beds, the capacity of the fine beds has remained constant. That has had fluctuations, and at first its fluctuations followed very much those of the coarse bed, but then, after the rest, it went up, and it has still remained at a good working capacity.

3921. Of course, the necessity for giving the beds a rest, say, of three or four weeks, is a very serious thing in actual working?—Oh, yes.

3922. It means that you might have to provide double the area of the filters?—It merely becomes a question of what is the necessary capacity of coarse beds, and I venture to think from the general experience that if you allow the road grit and the coarser matters to settle out, which you can by a screen, and by a catch-pit for the road grit; keep that off the bed, the fine suspended

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matters in the sewage might be put upon the beds at the rate of two fillings a day for continuous work.

3923. For fine beds?—For coarse beds. For fine beds unquestionably you can keep them as long as you like at three fillings a day. May I just remind you, sir, of what I have said on another occasion, with regard to this destruction of sludge upon the beds, that when we commenced these experiments at Barking, the sewage was run through the beds almost continuously, with the view to ascertain what was their capacity. At the first it was found that they could treat 1,000,000 gallons a day. Then, as the beds got choked with the sludge, the rate at which the water would pass through was reduced to 200,000 gallons a day per acre, and the assumption was, The whole thing is useless, an utter failure, and won't do at all. When we altered the method of working, instead of running the sewage through continuously, and allowing a deposit of sludge to accumulate upon the surface, we gave the bed, first of all, some. I think it was about six or seven weeks before we got it fairly sweet, and some two or three months before we commenced experiments again, but after we had got the bed into a sweet condition merely by allowing the organisms in the bed time to do their work, we were able to work that bed intermittently at the rate of 1,000,000 gallons per acre per day, and so far as I know, it is still working at that rate, or was when last I had to do with it; so that there we have a positive instance of how a bed may be overworked, may get into a condition in which it may be described, and was described, as an absolute failure, and yet by giving it a sufficient period of rest it recovered itself, and was able to do the initial quantity of work with which it first started.

3924. Then you must make provision for allowing that quantity of rest in your area of filters?—Yes.

3925. You must make that provision?—It comes to this; our coarse beds will have to be of larger area than our fine beds. The fine beds can work three fillings a day; the coarse beds can work two fillings a day, provided that the coarser matters of the sewage are kept out by a screening or straining, and they can be easily disposed of. That is, as far as I am able to see, the present outcome of all that has been done upon the question.

3926. What time elapses before a bed is mature?—At Sutton we began to get good results in about three weeks. At Leeds, I think, it took something like—more like three months, but, of course, a good deal depends upon the temperature and the season. If it is in the summer time, I should say you would get a bed into a fairly mature condition almost in a matter of days.

3927. That is an important thing, because in a town which is going to adopt this process for the first time the purification of the sewage will depend on the time which elapses before a bed is matured?—I hardly think that is so, sir. If you take a perfectly clean bed, and you put sewage upon it in this way, you will at once get an effluent which will be satisfactory—fairly satisfactory, but you will not get the full process of nitrification at work. You will not get the work so well done as it will be done, say, in two or three weeks time, but as an initial thing you will get an infinitely better effluent than you will get by any process of chemical precipitation; and on the old process of filtration it was assumed that the newer the bed the better the result.

3928. What are the considerations that determine the initial ratio whether as regards area or liquid capacity of the coarse to the fine filters?—Oh, I beg your pardon; well, simply by measurement. We have found that in many cases, indeed, in most cases, you have to allow about 15 to 20 per cent. more capacity for the fine bed, the initial capacity, by reason of the finer material taking up more space, being more closely packed, and you have not so much interstitial space between the particles as you would have in the case of the coarse bed, and, therefore, you must have a larger area, given the same bed to hold the water, than you would have in the coarse bed.

3929. Is that a fixed ratio?—15 to 20 per cent.: it depends on the size of the materials of which the bed is made. You may take it at 20 per cent.; the capacity of the fine bed must be about 20 per cent. more.

3930. That proportion of one-third the water capacity of the filter when charged, does that apply also to the fine filter: does that apply to both?—Well, with that difference that the capacity of the fine bed is so much less, and therefore you have to make the area larger.

3931. Yes, quite so. Have you found out what that proportion is? In, we will say, designing a fine bed, what proportion of the cubical contents would you estimate for the liquid capacity of the fine bed as distinguished from the coarse bed. You gave us the coarse bed at about 30 per cent.?—Well, take it in this way; take the capacity of the coarse bed at 30 per cent., then we allow more for the size of the fine bed to compensate for the difference in the water capacity.

3932. (*Mr. Killick.*) I have only one question to ask you, I think, Mr. Dibdin: What is your opinion of the relative value of coal as a filtering material?—I gave some information upon that in my evidence in chief. The facts were summarising the conclusions of certain laboratory experiments, that we found that four acres of coal filter of a given depth would be required to treat the sewage which could be dealt with by three acres of coke breeze of the same depth, and that was to say, I assume, that we got practically the same degree of purification. But coal there simply supplies surface, that is my theory; I may be wrong; I am only too pleased if I can be shown to be wrong so as to get the right theory; but that bacterial bed, as I call it, may be taken as a surface—an extended surface; and whether that surface is upon coal, coke, flint, cinders or anything else I do not think makes much difference, it is only a question of which is found to be the best in practice, and while you can get admirable results with coal, I know of nothing at present to make me prefer it to any other material.

3933. Just one other matter. Your four hours permanganate test is made at a temperature of 80° Fahr?—Yes.

3934. Sir Henry Roscoe's is made at 60° Fahr.?—I take 80° because that is the temperature fixed by the Society of Public Analysts. I do not think it makes very much difference under normal conditions, but it is just as well if the Society of Public Analysts have adopted a standard to use it for the sake of uniformity.

3935. Practically allowing for the difference in quantities, you think the one test is as good as another?—Both will show a bad sewage to be a bad sewage, and a good effluent to be a good effluent.

3936. (*Colonel Harding.*) Reverting to the experiments with storm waters, you told us that you were able to flow sewage, diluted more or less, for a number of consecutive hours over the beds without throwing the beds out of order?—Yes.

3937. And that you had reason to think that there was no reduction in capacity consequently upon such continuous flow?—Yes; I think that is fairly so. Perhaps I have a figure here taking those two tables together. Well, bed No. 2 treated 161,000 gallons of sewage and storm water in ten hours on November the 28th. On October the 13th the capacity of that bed—the water capacity—was 13½ per cent., and on November 30th it was 12 per cent., so that there was a reduction of 1½ per cent., but the reduction was from October 13th to November 30th, so that that would not be more, perhaps, than the ordinary reduction. No. 3 bed: I have a comparable measurement; on November the 28th it treated in 9 hours and 45 minutes 161,460 gallons of mixed sewage and storm water; on October 12th the water capacity of the bed was 17 per cent. On December the 3rd the water capacity was the same, 17 per cent., so in that case there was no alteration at all.

3938. I am rather surprised at that result. You explain it, I think, Mr. Dibdin, by saying that there was no more sewage brought down, but that there was more water brought down?—That is clearly so.

3939. But surely in the first storm waters following after dry weather you have quite a large quantity of organic débris brought down from road washings, clearing out of gullies, and so on, have you not?—Oh, the first rush of a storm water is always much worse than afterwards.

3940. So that one would expect by allowing not only the later, but the first rush of storm waters to flow continuously over a bed, that there would be very considerable reduction of capacity?—Especially if it was the combined system where road sweepings were taken in. Then, of course, the circumstances would be different. At Sutton we have a separate system, so we do not get the difficulty of the road sweepings.

3941. But where you have the combined systems you would expect that the passing of storm waters over the bed would lead to a considerable reduction of capacity?—No, I do not think it would, because in that case undoubtedly a grit chamber ought to be provided.

3942. I am assuming there was not?—If there was no ... chamber then certainly I would look for some re-reduction owing to the road grit.

3943. But apart from grit, there would be organic matter brought down by the storm water?—I do not think it would be very much after the first rush, which would not be treated as storm water, but as ordinary sewage. Then, when the beds were unable to deal with the increased flow of sewage in the normal way, and the sewage being so weak in character, it could then be put over one or more of the beds by this method of streaming, and that would not injure the beds.

3944. Then your experience in these experiments was that you could treat the storm waters for a number of consecutive hours upon the beds, and obtain results which were sufficiently good for the purpose, but not so good as those which you obtained by the ordinary working?—Not quite as good. If we state it upon percentage of purification, the sewage not being so strong, of course with an equally good effluent the purification would not be so high, although the quality of the effluent might be sufficient. We may consider the albuminoid ammonia in these different storm water effluents as compared with what we get in the effluent from the intermittent treatment of sewage. Albuminoid ammonia is ·08, ·06; in one ·29, but that was an exceptional one, ·11, ·15, ·07, ·08, ·07, and after returning to intermittent work ·06, so that the quality of the effluents was very much the same all along. The oxygen absorbed would be in the four hours ·68, ·56, ·25, ·13; then there is one exceptional one, ·22, ·98, ·87, ·70 so that practically there is not very much difference. There are variations, but on the whole you may take it that the quality of the storm water effluent obtained in that way would be quite equal to that of the sewage effluent.

3945. Though showing a smaller rate of purification?—Though showing a smaller percentage of purification, of course being on a more dilute sewage.

3945*a*. Then would you consider it advisable to provide separate filters for dealing with storm waters, and to let the filters which are dealing with ordinary sewage go on during rainy weather dealing with the same quantity that they do in dry weather?—These experiments distinctly point to the fact that you may use the beds that are used for ordinary sewage for the treatment of the storm water because these have been treating sewage all along.

3946. (*Major-General Carey.*) Up to a certain point?—On the intermittent principle since they were first constructed.

3947. Up to a certain volume surely, because you told me in answer to my question that there was a dilution—a very small dilution?—A very small dilution, because it is a separate system of sewage, 1½, say to 2, would be the difference.

3948. (*Colonel Harding.*) But if these results are reliable, surely they point to the possibility of being able to work the filters under ordinary conditions also to some extent on a continuous plan?—So you can.

3949. Then have you experimented to find out for how many hours you might allow the flow to continue through the filter with satisfactory results?—Having regard to the original experiments I mentioned this morning, at Barking, when we worked the beds through continuously, and found that their working capacity was reduced from 1,000,000 gallons to 200,000 gallons per acre per day, I have never felt inclined to repeat that experience, because we found that by the intermittent working we could keep the five beds working at the rate of 1,000,000 gallons.

3950. I quite appreciate that you believe that a certain number of hours of aeration is absolutely necessary?—With crude sewage especially.

3951. But would it not be possible to obtain more work through a filter if you were to give it twice in the twenty-four hours an empty rest of four hours, and use the time so gained for continuous flow?—Say continuous flow of night sewage for instance, of the light night sewage.

3952. Well, take day sewage as it is; for instance, you take an hour to fill your bed and then you allow the flow to continue for six hours more, then you stop the flow and it takes an hour to empty; you then allow four hours rest; that would make up a cycle of twelve hours?—Yes.

3953. Have you experimented at all to see whether that is practical, because it seems to me that if your experiments with storm water are reliable they rather point to the possibility of doing this?—I quite follow you, and I think that might very well be done with the weak night sewage, but I do not think it would be a good plan with the day sewage. We did something of the kind with our No. 2 bed, the one that was stratified, and from time to time that bed gave considerable quantities of sulphides and sulphuretted hydrogen, and it was not satisfactory, but whether it would have done that if we had used it, if the bed had been constructed of the same sized material right down its depth I cannot point to any special experiment to answer your question; but unless the sewage was, say, weak night sewage, I should doubt it. Well, I should like to see the result; I think it is worth trying.

3954. Now as to the reduction of capacity of the coarse beds, I should like to know what you find to be the form of the accumulations. They do not take the form of sludge accumulating in the bottom of the bed, do they?—No, the accumulation is very much more in the upper layers, where in consequence of that portion having less water, being in contact with water for a less time, it is the last to be filled, and it is the first part of the bed to be emptied; there the deposit upon the surface of the coke is in a pasty condition, soft, very soft indeed, but still having a certain amount of consistency. A piece will support its own shape for a little while, but as you proceed down in the depths of the bed, and a very short distance below the surface it begins to get more liquid—there is more and more water until it is perfectly liquid, it would not hold its own shape at all, it is a sort of liquid mud.

3955. Then the accumulations take the form of deposit upon the coke, which deposit in the upper layers is drier, and in the lower layers very much wetter?—That is so.

3956. You had the opportunity recently of digging down in Leeds to the bottom of the coarse bed?—That is so.

3957. It might perhaps interest the Commission if you explained what you found to be the condition of the bed; was there, for instance, any putrid smell in any part of it?

3958. (*Professor Foster.*) Might we ask what was the history of the bed just previously to its being dug into?

3959. (*Colonel Harding.*) It had been continuously working for some three months upon partially settled sewage?—The bed had had more than twelve months work, and the rough of the suspended matters had recently been taken out by allowing the sewage to pass through, I understood, the first of the set of precipitation tanks. It takes about forty minutes for it to pass through that tank, so that you may say it had about forty minutes rough settlement. Well, you could hardly call it a settlement, and yet it was allowed to settle as the sewage was travelling at considerable velocity through the tank during the time, so that the settlement was not a complete settlement in the sense that the whole of the suspended matters were taken out. The heavy matters were only removed or partially removed. I went all over the bed very carefully, and there was a hole dug right down to the very bottom of the bed, and I had samples taken from different parts, and nowhere on the bed could I detect any odour whatever. The samples of coke taken up at different depths had only that usual slight earthy odour; there was no sign of putrefactive odour at all. The top portions of the coke were fairly dry, with a sort of plastic clay-like stuff dark in colour attached to them, and as we proceeded down the deposit on the coke became more and more liquid, until it had more the appearance of liquid mud at the bottom—on a particle of coke being taken up, the deposit upon it would drop away like liquid mud. I took samples of this material, mixing them from the top to the bottom of the bed so as to get a fair average, and I found as the result of careful examination that they contained 85 per cent. of water, about 7½ per cent. of organic matter, and 7 per cent. of mineral matter, which consisted of about equal proportions of oxide of iron and silica. The organic matter under the microscope I found to consist of particles of true sewage *débris*, muscular fibre, spiral vessels, and such like matters, but with these large numbers of organisms, many of them being baccili and micrococci, and so on, were present in very large numbers, many of them freely moving about. But what struck me most was the presence of colonies of baccili. On being squeezed out between the microscope slide and the cover glass they spread out as a mass, and it could be clearly seen that of this organic matter undoubtedly a very large proportion was really living organic matter.

3960. (*Professor Foster.*) How much would you say—one half or one third?—As you know, it is very difficult.

3961. Oh, quite roughly?—The preponderance of these

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was so great that I should not hesitate to say, as a matter of opinion, probably not far short of one half of the whole thing was simply alive, and when under an ordinary observation you would see a granular particle, which you might easily pass over as so much amorphous organic matter, under the higher powers, it was found to be colonies of micrococci, so that I should feel inclined to assume that at least one half of the organic matter was living matter.

3962. Were the micrococci specially abundant. I mean more abundant than the bacteria or baccili?—I should not like to say that, sir.

3963. (*Colonel Harding.*) Then, Mr. Dibdin, water formed the greater part of this deposit?—85 per cent.—85½ per cent.

3964. So that the reduction of capacity may be said to arise from the retaining of water in the filter, or, in other words, be due to the filter not emptying during the periods of rest?—Clearly because the water is contained partly in the interstices of the coke, and in combination with this muddy deposit, and if the filter bed could be dried absolutely its capacity would be approximate to what it was originally, but by reason of this quantity of water being retained in the bed the quantity of water which could be put into the bed would be reduced proportionately.

3965. As a fact, during the whole period of the rest there is a flow from the bed?—Yes.

3966. A trickling through the bottom?—Yes. You can quite understand if you have a mass of coke, and you draw away the water, you have constantly trickling down the sides of each particle of coke a certain quantity of water, and that will accumulate at the bottom, and, as matter of fact, it may be days or weeks before a bed will cease to give a certain small trickle of effluent.

3967. Then, do you not think that the reduction of capacity may therefore be ascribed in part to the breaking down of the coke itself, those particles broken off from the larger pieces of coke; would not this account for the reduction of capacity. These smaller particles coming together and forming *débris* in the lower part of the bed would probably by capillary attraction retain the water, and so prevent the usual emptying of the filter?—Yes. I do not know that the breaking down of the coke would have much to do with it, except from the point of view that the capillary attraction might perhaps hold somewhat more; because, suppose you took a fragment of coke you would have a certain amount of water held up by capillary attraction upon the surface of that, but if you break up that piece of coke into half then you have additional surfaces exposed, and each of those new surfaces would hold a certain quantity of water, but having regard to the fact that the coke in a bed is lying there as a mass, although it has been dug into here and there, still the disturbance is very small as compared with the whole mass. I should hardly think that any breaking of the coke would have any material effect. I think that the quantity of water which is held by the matters deposited in the bed would account for it all, and as these matters get broken down by the sewage so much water passes away with them, and then in that case your capacity goes up again.

3968. Then how should you account for the somewhat rapid reduction of capacity of a rough bed when once it has been established?—Well, I must confess there are problems here which require investigation. Whether or not in the case of Leeds, the iron has so much to do with it in the way of having an antiseptic action or not is one which I must confess I am not quite happy about, because if that was so, if the iron was the only thing at fault then we ought to have no reduction of capacity at Sutton, because we have no iron. But, of course, we do get a reduction of capacity, and the problem we have before us now is as to what will be the maximum reduction of capacity consistent with the beds keeping and remaining in a good working condition. They will work, give a perfectly sweet and good effluent when the capacity is reduced down to even 10 per cent.—12 per cent.; the effluent is admirable, nothing whatever the matter with it, in fact we get a better one than we do when the capacity is at its normal. But the question arises will it keep at 12 per cent.? I cannot help looking at these tables, and I say yes, it will go above. It has gone above at Sutton. We had reduced from 32 per cent. in November, 1896, to 12 per cent. on October 6th, 1898, in two years, and the argument would probably clearly be to any impartial person looking at that: Oh, the whole thing is done for. Well, we go on. November 27th, its capacity has gone up to 13, December 5th it has gone up to 17¼ per cent., then on January 11th it goes down to 14 per cent., so that we get here from October 6th to January 11th, a wavering between 12 to 17½ per cent., and just as that bed might have been said to be perfectly useless a few weeks, say three months after its start, it keeps on working; it has three fillings a day, and the effluents are admirable. Well, let it be said that its maximum working capacity is 12 per cent. If you can keep a bed to that, a water capacity of 12 per cent., and maintain that, with two to three fillings a day, then you get a result such as we never dared to dream of a very short time back. I am allowing for the very worst possible conditions, and, therefore, I cannot say, having these facts before me, with a sewage in which there is no iron—practically none—we cannot put the reduction of the capacity of the Leeds bed down to the iron.

3969. But you speak of a reduction to 12 per cent.?—Down to 12 per cent.

3970. 12 per cent. of the total capacity of the bed?—Of the total capacity of the empty tank.

3971. (*Major-General Carey.*) It is the reduction of the original water capacity to 12 per cent?—It is the reduction of the original water capacity of 32 per cent. of the tank to 12 per cent. of the tank; that is to say, a reduction to really one-ninth of the original total cubic contents.

3972. (*Colonel Harding.*) Take the measures for the Leeds bed; the original capacity of the bed before any coke was put into it, was roughly 180,000 gallons?—Yes.

3973. During the greater part of the year 1898 the working capacity was 45,000 gallons per filling?—Yes.

3974. Well, that is 25 per cent.?—Yes. Then at Sutton we work about one-half that on one of the beds.

3975 At Sutton you work about one-half that?—At Sutton we work about half that

3976 Then at the worst Leeds has not approached anywhere near the loss of capacity that you have met with at Sutton?—No, and we have worked for 2¼ years, and we have had it fluctuating down to 12 per cent. and up to 18 per cent., and still it is working three times a day and giving good results.

3977. The reduction of capacity does not necessarily involve bad results as to effluent, but rather the contrary?—On the contrary some of our results are undoubtedly best when the capacity of the bed is lowest.

3978. I suppose you would consider that the recent results at Leeds, of which you have had experience in analysing in your laboratory, are the best that have been attained?—Yes; I think that was shown by the Tables I have put in.

3979. Although the capacity was reduced to its lowest?—Yes; that is the point, although the capacity gradually went down; and to one looking at it purely from the question of capacity, it would appear as if the whole thing was going to be a dead failure, but when you looked at the results, the effluents you were getting, it was seen that the results were excellent, and the only question was as to what is the total amount of work that you can do with an acre of these beds in perpetuity, or until such time as it may be necessary to renew the stuff or to shift the stuff in the bed.

3980. Then it would be clearly a valuable experiment to make to continue working a bed notwithstanding its steady reduction of capacity to its ultimate issue?—I strongly advise that. I strongly advise that to find out what the bed will not do, and the only way you can do that is to go on working it. If it proves that in the long run the quantity that it will take is so small that the expenses of the bed and the renewal of the bed becomes too heavy an amount we know exactly where we are, but until we have proved that point I cannot positively state anything upon it except that up to the present the bed is doing so much work and doing it satisfactorily. The question is this: if it is to be stated that it shall not cost more than a certain amount to treat 1,000,000 gallons of sewage; then we have a monetary standard to go by as to what we may call efficient or non-efficient, because, supposing you were to say, for the sake of argument, "You shall not spend more than 10s. a million gallons for treating the sewage, never mind how good your results may be"; then we would say the process would be a failure if it cost 10s. 6d., although the results may be excellent, but if the process will carry out the purification of the sewage for 9s. 6d., we will say, per million gallons, then are we to take it that that would be a satisfactory result, and that is really to my mind what is the argument with regard to these beds. That they will treat the sewage; that they will dispose of the sludge I venture to think, with all due submission, is as an ascertained fact, because if we

have, say take that original Sutton bed, to throw out the whole of the material in that and to put in new we should have that bed, we know, capable of working for another 2½ years; but as a matter of fact it has not yet come to the pass when it is necessary to disturb that bed in any way. It is working well, it is a very good digester, and it is doing its work, and if we are to limit what I may call the success of the process to that point at which it is to cost us so much money, then I say we have another standard. I do not know whether I have made myself clear, but it really comes to this: the process is clearly one which will purify sewage, the only question we have to ascertain is, say take it over a period of five or ten years, what will be the cost of doing it?

3981. Then you suggest that notwithstanding the reduction of capacity there will be no reduction of the volume treated in twenty-four hours, because you may, when the bed is thoroughly established, increase the number of fillings?—Well, it appears to be so. It all depends upon the quality of the sewage. In some cases where it is very strong you must modify that, in other cases where it is very dilute sewage you may undoubtedly get a much larger amount of work done for your area and depth.

3982. (*Dr. Russell.*) There is no doubt that, as you put it, the ultimate result of this phenomenon of reduced capacity works out in the extent of engineering works and the capital outlay; but still the scientific fact remains, and one would like to know what explanation can be arrived at in regard to it. What you have said amounts very much to saying, as you watched the diminution of this capacity, that: "Oh it's all right. What has happened before will happen again; it will recover." But have you applied your mind to the consideration of what is really behind this fact. What is the explanation; under what conditions does the cubic capacity diminish and then recover itself?—I think the continuation of the process of hydrolysis, the breaking down and rendering into solution the organic matters, which is carried on by the bacteria in a bed, accounts for this increase of capacity; but if you give them time, the bed will recover its initial capacity, except for the small amount of mineral matter. Then I say give the bacteria time and the rest will go; that is, 7 per cent. of organic matter and the 85 per cent. of water will all go with it, and the bed will recover itself entirely, because that happened with the original fine bed at Barking, and I had the same thing as I have pointed out to the Commission at Aylesbury. There by accident a quantity of sludge was put upon the fine beds, and the beds became perfectly useless, but by rest they recovered themselves completely.

3983. I gather that one set of circumstances, from what you said to Colonel Harding, was this, that an addition takes place to the particles retained in the filter, that this increases capillary attraction, and leads to an accumulation of water, and that as the bacterial action went on of course the particles diminish and the capillary attraction decreases, and the water flowed off containing dissolved organic matter?—That would be so. I think that is pretty clear. It quite agrees with my own experiments with meat, that as the meat gradually dissolved so of course the capacity of the bed became greater, and you may take it it does not matter whether your particle of organic matter is a microscopic atom of muscular fibre or a larger particle, the same action will take place.

3984. Then it follows that this process of recovery would go on in warm weather, in summer weather?—Very much more so in the hot weather. That was shown most clearly by the Massachusetts experiments, and quite in conformity with all my own results, that in the warm weather you get bacterial action in an infinitely greater rate; in fact, it is almost dormant during the severe cold weather; the beds store up stuff and the bacteria will overtake their work and destroy more per day than is supplied to them during the warm weather in summer.

3985. So that if your water capacity was going back during the winter you would expect that it would recover during the warm weather of the summer?—Oh, that is so. I have no doubt whatever. That is quite in conformity with this table on Leeds. There we started in the winter, and our capacity went down to June. On the 9th April it was 42,000 gallons, nearly 43,000 gallons. There was a steady decline, then on the 16th June it went up to 43,000 gallons after rest. It is a pity the enforced rest took place; of course it could not possibly be helped; the water capacity on the 28th July was 56,000 gallons. It varied; it went down to 45,000, 40 000; September 46,000 again, but it shows there that when we ceased to put on the crude unsettled sewage, and the capacity was 40,000 when the settled sewage was put on, then the capacity rose to 46,000 gallons, showing that there was a destruction of the matters in the bed to the extent of 6,000 gallons, although it was receiving settled sewage; but then the settled sewage carried in a considerable quantity of organic matter; yet in spite of that daily increment of organic matter the capacity of the bed continued to rise. Then with the advent of the cooler weather the capacity has now gone down, I understood Colonel Harding to say, to 30,000 gallons.

3986. (*Colonel Harding.*) Oh, more than that—30,000 to 35,000 gallons?—35,000 gallons, and probably with the advent of warm weather, if the mineral matter be kept off you would have that by next summer up again to 45,000 to 50,000 gallons. It appears to me that that would be so.

3987. (*Major-General Carey.*) I do not see how it would be possible to design any works on these varying data?—Except this, sir, that if you take the minimum data. Here we are saying what can be done upon the beds, but if you take the worst results you have here, not your best or your average, take your worst results and design your works on that.

3988. But in your Leeds experiment 46,000 gallons on October 6th did not represent finality at all, as Colonel Harding has pointed out to you; you have gone on daily reducing to 30,000?—Yes; because I am speaking there with regard to the temperature. That reduction follows the cooler weather, that as the weather gets colder you get your bacterial action less active, and with the return of the warm weather you will get it accelerating, and the result will be that you will get in a bed just the average quantity of sewage per day with which it can successfully deal. A table showing the daily results would oscillate, showing that the capacity of the bed in the winter would be much less than it is in the summer.

3989. That all really means continued experiments to ascertain these as undoubted facts?—It does with regard to the maximum capacity of the beds, but not with regard to the capability of the beds.

3990. The maximum working capacity?—Yes, if you base your works upon what you know to be the minimum, upon your safety point, then you may proceed with every confidence.

3991. If you have got to a safety point?—I do not know how long it may be. The fine beds have gone on for seven years, and there is no trouble with these from beginning to end. There is no trouble with the coarse beds. The only question with the coarse beds is how much sewage can they take, and if we have the capacity of coarse beds, which will deal with the sewage on the minimum of our known results, then we have a safety point, I think, beyond which we need not go.

3992. In the Leeds report, page 46, it is stated: "It has been assumed from the experiments at Sutton and elsewhere, with domestic sewage, that the working capacity of a bacteria bed fully established is two-thirds of the original water capacity." That does not agree with what you have stated as to the 21 per cent?—At the time we started the Leeds experiments our capacity of the Sutton beds was 32 per cent. That was after nine months working.

3993. (*Colonel Harding.*) But when speaking of 32 per cent. you are speaking of 32 per cent. of the original total capacity?—32 per cent. of the original total capacity.

3994. But in the passage referred to, where it is said on your authority that the normal capacity would be two-thirds, what is there referred to is two-thirds of the water capacity, which is quite a different thing, is it not?—Well, if you take the case of Leeds they work out very much the same thing. It is one-third of the total capacity. If you take the two-thirds, the water capacity there as 80, the working capacity came down to two-thirds of that, something about 55 we will say. I am not quite certain that that expression is mine, the two-thirds of the water capacity, because when I read it in this report it seemed to me a new expression entirely. But notwithstanding, it so closely approximates to the facts, that I let it run. It was the same thing; one-third of the total capacity; the total capacity of the Leeds beds 165,000, the working capacity 55,000, that is to say the normal until the reduction took place.

3995. The difference is quite small?—Quite small.

3996. The total capacity was 180,000 gallons; one-third of that would be 60,000 gallons?—It is practically the same thing.

3997. And the two-thirds of the water capacity is 55,000 gallons?—Yes; it came to the same thing.

3998. It is substantially the same thing?—Yes.

Mr. W. J. Dibdin, F.I.C., F.C.S.

18 Jan. 1899.

3999. (*Dr. Russell.*) I understood you to say that during the resting full period a deposit was taking place in the pores of the filters and the particles?—I think it must be.

4000. It seems a reasonable theory. That points to another position—that a filter bed used after a process of precipitation will not require such a long resting period, as in your case, when you deal with crude sewage?—Yes.

4001. Do the theory you have given in expressing percentages of time the distribution of these various parts of the life of a filter, as it were, between filling, resting full, emptying, resting empty?—The time is not given there, but the principle upon which it always appears to me to be the best to act is to fill a bed as rapidly as you can; in order to save time, the faster you fill a bed the more time you have for the subsequent operations, because we cannot suppose that there is very much work done, deposited in the bed during the period of filling. Fill it up as fast as you can, then let it rest two hours, and then draw off as slowly as you can, but I do not think it makes any very material difference whether you are a little longer or shorter time in drawing off, except that, of course, the quicker you can draw it consistent with fairly good effluent the more time you will have to——

4002. The two active periods being the resting full and the resting empty?—The resting full and the resting empty, yes.

4003. (*Colonel Harding.*) There is just one point, if I might bring this out. The last dribbling from a bed you find to give the best results?—Yes, that is almost always the case.

4004. Is that quite distinctly so?—I think so, yes.

4005. Then would it not be possible to entertain that condition by continuing a dribbling supply at the same rate?—Yes; but then the question is whether the total quantity of work you would get done in the bed would be sufficient for your purpose; but, of course, if you could, decidedly; but then it becomes a question of sufficient quantity.

4006. (*Major-General Carey.*) It is generally assumed that the filters will be worked night and day?—Well, that would have to be dealt with in regard to the size of the works. In small works, where the sewage can be stored for the night, well, it saves cost; it saves labour, it practically saves a night attendant if all the work can be done in the day, and the sewage all pumped into a tank, and then pumped all up in the morning with the morning's sewage; but there you have, as in almost every case you have, the fact that the night soil is very weak, very poor. I think that that might very well be worked upon the lines upon which the sewage has been treated from a house upon this principle. It was the first place upon which the coarse beds were tried, and that is the Claybury Asylum; not the sewage of the whole of the Asylum, but nearly all what they call the private patients ward. The old Mansion House has about fifty people in it. There the sewage flows on to a coarse bed, having a capacity sufficient to take the twenty-four hours' flow, and in the morning an attendant diverts the flow of sewage on to a corresponding bed, and opens the outlet of the one that has been receiving the sewage, and the effluent from that individual case goes straight away into the brook. They do not even use a second fine bed.

4007. That is the night sewage?—No; it is the twenty-four hours, the whole twenty-four hours. That has been working now for over three years, and giving every satisfaction. It stopped a nuisance they were committing before. Now, if that can be done with the whole of the twenty-four hours' flow of sewage, why can we not do the same thing with the weak night sewage, only let it go on to a bed having a capacity sufficient to take the whole of the night's flow.

4008. Then how long would it remain in the filter?—In the morning, as soon as the man arrived he would divert the sewage on to the ordinary beds, and turn it off from the night flow bed into the fine beds.

4009. But would not the fact that the sewage which remained, weak as it was, had remained in the filter all night, render it putrid or liable to become putrid?—No; that has not been found to be the case at Claybury, and there is another one been put down at Northumberland, and various others. It has not been found to be the case. The thing works very well indeed, and I heard only the other day of a place—I wanted to get the full particulars, but unfortunately I was prevented for the moment—where they had been really using this intermittent system of working, which, after all, is only a modification, as I explained before, of Sir Edward Frankland's downward intermittent process, for over twelve years. They did not know exactly what they had been doing, but all they knew was that they had some sewage, and they had some heaps of cinders, and they turned their sewage for several days in succession upon one heap, and then they turned it for several days in succession upon the other heap, and as it happened they had no effluent. They wondered where the water went to. It all disappeared, but afterwards they found it soaked away through the subsoil into the river without anyone ever guessing where it was. It was so far purified going through the subsoil that it went away without any difficulty. That is one way. After about twelve years, when they heard of our Sutton work, they said: "Why, yes, of course, this is just what we have been doing all along"; and there are numerous other cases.

4010. The case is rather different in one sense, that at Sutton you are on clay and the water would not percolate away?—It would not do in the case of Sutton, but I am speaking with regard to the action on the bed.

4011. But the water would remain on the filter all night. It would not percolate through the subsoil?—No; it would remain in the filter, and then in the morning it would be diverted on the fine bed, and the bed would have all day to aerate; in fact, we have been working beds in that way with fairly good results, in fact very good results, because the effluent in the fine bed is the same all along the line.

4012. As to the practical working of this process, do you think that the workmen, say, in a rural district could be depended on to open and close the filters at the appointed hours?—As a matter of fact they do, and I have found this, that these men, if they have some process to work with which they cannot give good results, get disheartened, and they are not perhaps quite so careful as they might be. I have known that with the old precipitation schemes. They would give almost anything to get rid of it, but with these beds, and with anything of this kind, it is like a man with a good engine, it is astonishing what pride they will take in their work when they begin to get results which are really satisfactory, and the thing is going along comfortably; these men will really take such pride in their work that they do not care what they do, just like a good engine driver will take care of his engine.

4013. If the thing is not properly supervised the whole thing would be probably a failure?—There is no objection to applying some automatic method of charging the beds if it is considered necessary; that is a matter of detail. I do not deal with that; that is an engineering question.

Mr. R. A. Tatton, M.I.C.E., re-called; and further Examined.

Mr. R. A. Tatton, M.I.C.E.

18 Jan. 1899.

Appendix No. 3.

4014-5. (*Chairman.*) You are good enough to come back to us to hand in some papers, which I am sure will be very valuable to us, and which I am afraid must have given you a great deal of trouble. You hand them in to us?—Yes, I do, my lord. I hand in a table showing the particulars as to the methods of sewage treatment adopted by the local authorities in the Mersey and Irwell Watershed, derived from information supplied by the authorities to the Joint Committee.

4016. I have only to say that we are extremely obliged to you for the trouble you have taken in the matter?—I am sure I am very glad indeed to be of any use; I think the tables really explain themselves. The summary at the end perhaps shows better, more concisely than the rest of the table. I would just make one remark, and that is that for the chemical precipitation alone the first instance given, "A," must really be disregarded entirely, because at the time that these samples were taken the works in question had very little sewage going to them, and therefore they were able to deal with that sewage satisfactorily by precipitation only. Of course it is a single instance. I think you must not place any reliance upon that at all, because we do not find in any case, except in this very exceptional one, that precipitation by itself is at all satisfactory. I do not know whether there is any further explanation that I could give of the tables.

4017. No, I think the tables must speak for themselves?—Yes.

4018. (*Sir Richard Thorne.*) May I ask you one question In your summary, Mr. Tatton, under the heading "Precipitation and artificial filtration" you have a Sub-heading (*e*), "Chemical Precipitation and Biological Filtration." "Domestic Sewage only." Then follows the word "none." Does that mean that there were no samples at all?—No; there were no samples at all with domestic sewage only. I simply put in that because that was one of the headings which I was asked to report upon separately, so that it might not appear that it had been left out.

Mr. R. A. Tatton, M.I.C.E. 18 Jan. 1899.

4019. (*Mr. Killick.*) There is one question I should like to ask, my lord. These samples are typical samples; they are comparatively a few number of samples. Your inspectors only take samples when they have reason to believe that there is some change in the works or in the method of working the works?—Well, it is not that entirely. We take samples periodically about every two or three months as a rule, but I think that these samples may be taken as typical samples, although you may say that they are very seldom taken, because the inspector visits the works very much more frequently; for instance, each of these works during the year would be visited perhaps twenty or thirty, or more than that number of times, and as a rule we find from the inspector's reports that the samples fairly well agree with those reports. Of course, they get into the way of judging pretty well whether the works are being properly looked after or whether they are not, and, therefore, I think that the samples, although few, give you a better idea than the numbers would really imply.

I would suggest, my Lord, that we ask the Inspector of the West Riding Rivers Board, and of the Ribble Watershed Committee, to prepare tables on a similar plan, so that we may have one table containing the whole critical analysis of the River Boards in the north.

Appendix No. 4.

Appendix No. 5.

(*Chairman.*) I think that would be very useful.

FIFTEENTH DAY.

Thursday, 19*th January*, 1899.

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary*

Dr. SIDNEY BARWISE, M.D. (Lond.), D.P.H. (Camb.), County Medical Officer of Derbyshire, called in; and Examined.

4020. (*Chairman.*) You are Dr. Sidney Barwise, County Medical Officer, of Derbyshire?—Yes, my lord. I am also a Fellow of the Sanitary Institute, past President of the Midland Branch of the Society of Medical Officers of Health, and was formerly Medical Officer of Health of the County Borough of Blackburn.

Dr. S. Barwise, M.D., D.P.H. 19 Jan. 1899.

4021. Would you give us an outline of your experience on the sewage question?—I have taken a general interest in the question since I have been a Medical Officer of Health, but during the last eight years I have had to inspect the various sewage disposal works within the County of Derby and collect samples of effluent therefrom, and to analyse them and to report to the Public Health Committee of the County Council as to whether pollution of the rivers is taking place. I am also acquainted with the literature of the subject, and have contributed papers at the Glasgow Conference of the British Institute of Public Health in 1895 and the Sanitary Institute in 1896, and I have lately published a small book upon the purification of sewage. I may say that I have in my district twenty-five sewage disposal works of an urban character, works purifying or purporting to purify the sewage of populations ranging from 4,000 to 40,000, and some fifty smaller schemes for hamlets and small towns, with populations ranging from 200 to 4,000. I have also investigated various modern methods of disposal, such as the Exeter septic process, Colonel Ducat's filters, Mr. Lowcock's filters, Mr. Garfield's filters, and such sterilising processes as the Amines process and the Baccillite process, Electrolysis, Hanson's process, and the arrangements which have been made recently for applying sewage by sprays on to filters and Mr. Lomax's method of intermittent flushes.

4022. Would you tell us first as to the Derbyshire schemes?—Well, speaking generally, they are all failures. One general conclusion that I have come to is that land which will purify sewage is much rarer than is generally supposed, at any rate so far as the County of Derby is concerned. I have here a geological map of the county, a reference to which will show that we have little land in Derbyshire which is really suitable. We have in the south a large tract of the New Red Marl, then to the north-west we have a large area of mountain limestone; then on the east of the county the surface of the coal measures, this is all unsuitable. I may say that there is only one spot in the county where land treatment alone is carried on satisfactorily, that is at Swadlincote. At Swadlincote the sewage from a population of 12,000 drains on to an area of sixty acres, giving 200 persons per acre. The geological formation is Bunter sandstone and drift, and we get a good effluent. We have one or two other good effluents from land, but in these cases the good effluents are due to dilution with spring water. On the other hand, as an example of unsuitable land, I cannot take a better example than our county asylum at Mickleover. Here the land is the stiff clay of the New Red Marl, and it is absolutely stiff. The sewage effluent—I will put the figures in, my lord; I do not know whether you wish me to read them—but on the average of six samples of the effluent, the organic ammonia contains ·20 parts per 100,000, and the Asylum Committee are so satisfied that the area of land is insufficient, although there are only twenty persons to the acre, that they have recently purchased ten more acres.

MICKLEOVER ASYLUM.

Parts per 100,000.

——	Total Solids.	Chlorine.	Free Ammonia.	Organic Ammonia.	Nitrogen as Nitrates
Drinking water -	82·	3·7	·000	·001	·6
Sewage - - -	107·8	9·2	2·5	·6	N
Effluent (average of 6 samples).	79·6	6·2	1·14	·20	·12

N.B.—A large quantity of rain water is used for washing.

They have been compelled to do this owing to the complaints which a neighbour has made and the action which he has threatened. In the summer time the Marl cracks and the sewage passes quite unpurified down to the drains. Then worms make holes direct from the surface down to the drains. I have also seen an excellent example of this at Brampton, in Derbyshire. At Brampton it is the stiff clay of the coal measures, and the sewage contains dye waste. In a recent trial hole that was dug on the farm it was possible to trace from the surface right down to the land drains

Dr. S. Barwise, M.D., D.P.H.
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the course of the sewage by its leaving the dye on the sides of the worm-holes—holes about the size of a pencil. Similar results occur in other places in the case of the stiff clay of the coal measures. Perhaps two examples will be sufficient: Whittington and Newbold. Upon these two areas the sewage of about 700 to 800 persons to the acre is dealt with, and it is supposed to be intermittent filtration. There is only a faint trace of nitrates in the effluents, which on the average of fourteen samples contained from ·28 to ·33 parts per 100,000 parts of organic ammonia. Attempts have been made to lighten our heavy clays in Derbyshire by digging in engine ashes; Draycott is an example of this. Here a large sum of money was spent in digging in ashes, but the only result has been that the sewage goes through the clay at certain parts, and at other parts it does not go through at all. The result is that where the ashes have been dug in those parts take the bulk of the sewage, and where it does go through little purification, if any, is effected. The conclusion that I have come to with regard to this stiff land is that if an effluent is to be produced containing from ·1 to ·15 of organic ammonia in the 100,000, at least one acre to every twenty-five persons ought to be taken. That is, if artificial filtration is not adopted; if there are not biological filters, and if there is not precipitation.

4023. (*Major-General Carey.*) You mean broad irrigation; twenty-five persons to the acre?—Yes, sir.

4024. You mean that is broad irrigation?—Yes, sir.

4025. You are not now speaking of intermittent filtration or the land laid out in plots?—I say this stiff clay land cannot act as an intermittent filter. Loans are sanctioned to lay it out for intermittent filtration, and it is laid out, but it is a physical impossibility to filter through material which is used to puddle the banks of reservoirs with. Brampton is a case in point of what is called intermittent filtration; the loan was sanctioned for intermittent filtration, and the only way the sewage goes through the clay is through the worm-holes and the cracks as I have described.

4026. Is it treated beforehand?—No.

4027. Is it treated before it goes on the land?—No, sir.

4028. Chemically treated?—No, sir. When, however, precipitation is adopted I have a number of results which I should like to put before the Commission. I have the results obtained at Alfreton, Ilkeston, Chesterfield, and Long Eaton. At Alfreton and Ilkeston the precipitation is effected by aluminoferric in conical-bottomed tanks. The average of the organic ammonia in that effluent is ·20 at Alfreton; ·27 at Ilkeston. At Alfreton there are 400 persons to the acre; at Ilkeston 500. At Chesterfield there are 735 people to the acre, and the effluent there contains ·41 of organic ammonia. At Long Eaton it also contains ·40. These are the average results of a number of analyses: 15 in the case of Alfreton, 15 in the case of Ilkeston, 23 in the case of Chesterfield, and four in the case of Long Eaton. Looking at these figures where precipitation is adopted, and you have this same stiff clay, I think there ought to be at least one acre for every 200 persons if you are not going to have biological filters; I think there ought to be one acre to every 200, even when precipitation is carried out really well, because it is carried out well at Alfreton. To show the relative purification effected by the precipitation part of the process and the land part, I have these results: Taking the organic ammonia at Alfreton, the average sewage contained 1·15, the average tank effluent ·38, and the land effluent ·20. I think these figures will give approximately the average purification effected by precipitation and irrigation or so-called intermittent filtration on clay land: In round numbers 1 the sewage, ·4 the tank effluent, and ·2 the land effluent. Taking the average of 100 samples of the effluents from schemes where precipitation is adopted and irrigation of stiff clay, the effluent contained ·45 parts of organic ammonia. That is higher than at Alfreton and Ilkeston, because in the case of Alfreton and Ilkeston the figures are taken from a limited number of samples, when I was able to get sewage tank effluent and land effluent; ·45 includes samples in which I did not get the sewage and the tank effluent as well. Even where the land is suitable—where it is good porous land—we have in our county a splendid example of failure in the Burton-on-Trent sewage farm. This farm is in my district. The population of Burton-on-Trent is 40,000; the sewage is from 5,000,000 to 6,000,000 gallons a day. They filter the sewage intermittently, and irrigate 450 acres of land, yet they have never been able to produce a single trace of nitrates in the effluent.

4029. Is that not largely mixed with brewery waste?—I am coming to that, sir. That is no doubt partly the reason. Allowing two-thirds of the land to be resting, they filter at the rate of eight or nine gallons of sewage to the square yard per day. As the sewage arrives at the pumping station it contains sometimes as much as four parts per 100,000 of sulphuretted hydrogen. Under the advice of Professor Dewar, lime is added at the pumping station—35 to 40 grains to the gallon, and the mixed sewage and lime is pumped out on to the land. Since that has been done there has been no smell to speak of from the sulphuretted hydrogen. After running in a channel about three or four feet wide along the land, the sludge deposits—it deposits very quickly, and you get an absolutely perfect tank effluent—you get liquor which is absolutely free from suspended matter, with which they irrigate. Although they have removed all the suspended matter, yet by irrigating with this clear liquor they have never yet produced any nitrates to my knowledge. In making that statement to the Mayor of Burton, the only rebutting statement which he made to me was that when they irrigated some new land which they had recently taken they did get a trace of nitrates. And further than having no nitrates, taking the average of thirty-six samples of the effluent, I find that it contains ·28 parts per 100,000 of organic ammonia.

4030. (*Chairman.*) Would you go on to speak as to any results obtained by biological filters that come within your knowledge?—Yes, my lord. Summing up what I have said, it amounts to this: that with the exception of the one farm which we have upon Bunter sandstone the other land schemes fail to produce nitrates, and have effluents containing from ·2 to ·4 parts of organic ammonia in the 100,000, and are for that reason, in my opinion, quite unsatisfactory. Then in contrast with these schemes the average of fifty results obtained from biological filters and precipitation is that the effluent contains ·095 parts of organic ammonia in the 100,000—that is, less than ·1 part of organic ammonia and ·4 parts of nitrogen as nitrates. Although these figures are a great improvement upon those previously given, they include the effluents from filters which had only been recently started at Chesterfield, and were producing bad effluents in their early stages. We have two small international schemes, that is, precipitation with a mixture of sulphate of iron and alumina sulphate, and filtration through sand and polarite, the filtration being at the rate of 270 gallons. These works give the following results:—·04 of organic ammonia and ·38 nitrogen as nitrates, in parts per 100,000; but I ought to say this, that they are works which have been carried out without the sanction of the Local Government Board by colliery companies, and they have coupled up the tank effluent to tap water so that dilution takes place as well as purification. The following are the results that I have obtained from biological filters, which have been constructed of coal:—

RESULTS obtained with Coal Filters.

	Number of Samples.	Organic Ammonia. Parts per 100,000.		Reduction of Organic Ammonia per Cent.
		Tank Effluent.	Filtrate.	
Chesterfield - -	11	·66	·17	76
Buxton - - -	5	·143	·035	75·6
Wolverhampton -	3	·38	·08	76
Lichfield - - -	1	·26	·08	69
Long Eaton - -	1	·48	·1	78
Kimberley - - -	1	·46	·16	65

At Long Eaton and Kimberley the sewage was being filtered far too quickly.

In the face of these results, I was anxious to try coal at the side of other biological filters. I could see no reason why coal should act better than other material, and at Buxton we had some comparative trials of filters of different construction, one of coal or a mixture of coal and destructor breeze—I call it coal, because it is the only filter which contains coal. As a matter of fact, it is not purely a coal filter; they could not get sufficient coal in the time, and they put some destructor breeze in. Coal, coke, and destructor breeze are the filters. The purification effected was as follows:—The coal filter reduces the organic ammonia 75·6 per cent., the coke 51 per cent., and the destructor breeze 55 per cent. In calculating the percentage of the purification effected, I

have reduced the organic ammonia in the tank effluent in proportion to the chlorines, so that I have made the purification effected as small as it possibly could be. The individual samples from which these averages are taken I have here, my lord.

BUXTON COMPARATIVE EXPERIMENTS.

Parts per 100,000.

	Organic Ammonia.	Nitrates.	Chlorine
TANK EFFLUENT	·132	Trace.	—
	·076	Trace.	2·3
	·075	Trace.	—
	* ·230	·05	2·8
	·140	Trace.	2·5
	·280	·05	2·4
Average	·155	·05	2·5
Reducing in proportion of Cl. 2·5 to 2·3.	·143	·05	2·3
COAL FILTER	* ·050	·42	2·3
	·032	·62	2·5
(Organic Ammonia reduced 75·6 per cent.)	·040	·45	2·4
	·020	·40	2·0
	·025	·50	2·0
Average	·035	·50	2·3
COKE FILTER	† ·054	—	—
	† ·050	—	—
(Organic Ammonia reduced 51 per cent.)	† ·052	·15	2·2
	* ·110	0·9	2·8
	·100	·40	2·5
	·080	·40	2·4
	.028	·36	2·0
	·040	·40	2·0
Average	·071	·33	2·3
DESTRUCTOR BREEZE FILTER	† ·052	—	—
	† ·064	—	—
(Organic Ammonia reduced 55 per cent.)	† ·040	·14	2·2
	* ·100	·18	2·8
	·090	·30	2·5
	·075	·30	2·4
	·031	·28	2·0
	·032	·40	2·0
Average	·065	·3	2·3

* Samples collected continuously from 2 till 5 p.m.
† Not included in average.

The average organic ammonia in the tank effluent is ·155, but I have reduced that ·155 in the proportion of the chlorine shown on the right-hand column, that is from 2·5 to 2·3, which reduced it to ·143. Then I have starred one particular sample, the organic ammonia in the tank effluent being ·230 and the chlorine being 2·8, and in each of the filtrates 2·8. That was a sample collected continuously in spots at a time, and I think that is an absolutely fair comparison in that particular sample. In that case the reduction effected by the coal is 79 per cent., by the coke 52 per cent., and by the destructor breeze 58 per cent.

4031. (*Colonel Harding.*) What was the relative size of the material?—I am coming to that; I think that is the solution, and although it was supposed that the quantity of sewage filtered per square yard was the same in each case, as a matter of fact I found that the coal filter was working at the rate of 500 gallons per superficial yard per twelve hours, the coke filter 270 gallons, and the destructor breeze 360. They were supposed to be the same, but, as a matter of fact, while that test lasted the coal was working at the rate of 42 gallons per square yard per hour. I do not think there is any doubt, first of all from my own results, and from the results which I know Dr. Reid has obtained at Tipton, that coal for some reason or other effects a very much larger percentage of purification than any other filtering medium yet tested, and I cannot help thinking that it is because the coal has been so very carefully washed, so that it is absolutely free from dust. The coal in all these coal filters has been washed so that it is absolutely free from dust. The result is that capillarity does not come in, and when the sewage is not applied to the filter it drains quite dry, and the air can enter into all the interstices of the filter.

4032. (*Professor Ramsay.*) Have these filters been long in action before you tested them?—Yes, they have; they have been in action now about eighteen months, and the efficiency is not falling off at all. I am rather missing a point. The Buxton tank effluent is a very good effluent. I think it is very important to mention the fact that tank effluents occasionally like this Buxton tank effluent contain a trace of nitrites. I found the Exeter tank effluent contain a trace of nitrites too. I think it makes it a very favourable effluent—to nitrefy. I should say that if the coal does act better than other material that has yet been tried it is because it has a clean fracture; it has no *cul de sac* for stagnant air to remain in, that it is washed free from dust, and is of such a size that the air can pass away into every part of the filter when it is drained dry. I have the size of the material here. The coal was of various sizes, but it was coal, speaking generally, which would stop on an eighth of an inch mesh, and would pass through a quarter of an inch mesh, although it varied slightly. It was coal which came from Staffordshire. The coal which we tried of the same size at Chesterfield did not act so well, I think the reason for that being that the Derbyshire coals are more shaley, and although they would pass through meshes similar to the Staffordshire coal and stop on meshes of the same size, yet being of a more shaley nature, they were packed closer than the cubical pieces of the Staffordshire coal, so that the size ought to depend upon the character of the coal. I should say that with our Derbyshire coal we ought to have bigger particles, bigger sizes than with the Staffordshire coal. I would generalise by saying that hard coal ought to be of smaller size, or, rather, put it the other way, a soft coal ought to be of larger size than a hard coal.

4033. (*Chairman.*) Have you any views as to the size of the filters or the rate of filtration?—I think that, except with an exceptionally good effluent such as that at Buxton containing nitrites, that the rate of filtration should be not exceeding 250 gallons to the square yard in the period of twelve hours, the filter then to have a rest of twelve hours. These filters at Buxton, and, in fact, all the filters that we have experimented with, have not been worked upon Mr. Dibdin's plan, but we have worked on similar lines to Colonel Ducat, that is to say, we have not blocked up the outlet of the filter; the sewage has been applied over the surface of the filter, and to see that too much is not put on there has been an arrangement to prevent more than the required quantity going on. The advantage of this is that the filter is much cheaper to construct. In the case of clay land we have simply dug a hole in the ground, filled it in with the coal, and sprayed the sewage over the top, and as long as the arrangement for applying this sewage is such that it prevents more than 250 gallons to the square yard going on, I think the arrangement is quite satisfactory. The only danger is that too much would be put on. The particular arrangement which seems to me to act best is an arrangement—not a patented arrangement, simply an arrangement of iron pipes with quarter-inch holes in them, over the top of the hole a plate of metal, the pipes being fed by an automatic flushing tank. What happens is this, that when there is a head of two feet the sewage impinges on the metal disc and spreads out in a wide circle; as the head diminishes the circle narrows, so that you get practically the same effect as a watering can over the surface of the filter.

4034. And does the raw sewage go on the filter?—No, my lord; in all the cases in Derbyshire the sewage has been precipitated first.

4035. (*Colonel Harding.*) What are these pipes made of; are they cast iron pipes?—They are ordinary gas pipes.

4036. Then they are wrought iron pipes?—Yes. wrought iron pipes.

4037. You have not any idea of the cost per given area of that system of distribution?—I have not, sir; but I do not think it is a big sum. The things have been very roughly made.

4038. (*Chairman.*) Have you anything to say about the present land requirments of the Local Government Board?—Of course I recognise that they have been wise in the past, and the knowledge that we have to-day they had not a few years ago, but I think that where the land is unsuitable, that if the Board could see their way to have an adequate area of filter in the place of land, that it would be a very great advantage generally. I would insist upon a very large margin of filters, and I think filters ought to be constructed of gradually increasing coarseness for the more rapid filtration of storm water. I would suggest that where sewage is diluted seven times, the rate of filtration might be 2,000 gallons to the square yard, when diluted eight times the rate of filtration might be 4,000, and so on, the rate of filtration going up in geometrical progression, the dilution in arithmetical, so with nine times dilution, 8,000 gallons to the square yard, and so on. I do not commit myself definitely to these figures, but use them to illustrate the principle.

4039. (*Major-General Carey.*) Per square yard of filter?—Yes, sir.

4040. It depends, does it not, on whether the filter can

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pass that quantity through?—I say I would have the filter constructed of gradually increasing coarseness of material. If the filter is made of large enough particles, I do not see any reason why it could not pass through any quantity—20,000 or 30,000 gallons, if made of stuff half-an-inch or an inch in size. The greatest difficulty we have had in Derbyshire in getting things carried out is on account of the Local Government Board's land requirements. I could not take a better case than that of the two Matlocks—Matlock and Matlock Bath. They both recognise that a scheme of purification ought to be carried out, but to comply with the Local Government Board's requirements with regard to land it would necessitate spoiling one of our beauty spots; we should have to have a sewage farm in front of Willersley Castle. Mr. Arkwright naturally objects to that, and I think any one who loves our scenery would object to one of our beauty spots being spoiled, but there are about six acres of land where a scheme could be carried out if it were not for the Local Government Board's requirements with regard to land. And, speaking generally, the same thing applies. There is the greatest difficulty. Take the case of Buxton. If Buxton were to go for any suitable land I do not know what they would do. They could not do anything without incurring an expense which would ruin Buxton. If you know where Buxton is on that map you will see you would have to go a very long way to get anything but limestone, which is full of cracks and crevices, and is quite unsuitable for sewage purification purposes.

4041. (*Chairman.*) Where the stream into which the sewage goes is to be used for drinking purposes or for washing, would you suggest any special measure of precaution?—I recognise at once that these biological filters, although they represent a higher percentage of chemical purification, do not effect so large an amount of bacteriological purification, and what I would suggest is that after it had gone through that chemical purification a subsequent continuous filtration through sand should take place like the filtration of water, a continuous biological straining, one square yard of filter being used for every 500 gallons per day of twenty-four hours. I think this would be a real safeguard, while by the land I do not think there would be a real safeguard.

4042. Have you anything to say about the precipitation tanks that you know of?—In Derbyshire we have a number of modifications of the Dortmund tank, that is, the conical-bottomed tank in which the sludge is removed without pumping off the top liquor. This arrangement is undoubtedly a very satisfactory arrangement, but our local authorities are put to great expense—it is their own fault I admit—by constructing the tanks of at least two people who profess to have obtained patent rights in a tank of that kind; and I suggest the Local Government Board should not sanction loans for patent arrangements without there was a primâ facie case for the validity of the patent. If you would allow me to show you in Colonel Moore's book the difference, for instance, between an ordinary Dortmund tank and a tank which is shown here as a patented tank (*showing*). That is the ordinary Dortmund tank; the sewage comes down the centre; the only difference between that and the tank which is supposed to be patented is that the sewage comes in at the side. I may say that I have had the advantage of reading an opinion by Mr. Fletcher Moulton, and on the strength of that opinion I have always advised authorities, when they have asked me, not to pay any patent rights for putting a tank of that kind down. But there is no doubt that a very large amount of the ratepayers' money has been spent upon such tanks. What I say is that I think when the Local Government Board sanctions a loan for paying a patent right that they should see that in the patent for which they are sanctioning the money, the ratepayers really have something for which they are spending their money.

4043. (*Sir Richard Thorne.*) Before you leave that would you kindly be a little more definite. The Local Government Board are to see that the ratepayers get their money's worth. Would you be a little more definite, because it is a little important that. What intervention on the part of the Local Government Board do you suggest: that they should refuse the loan unless these people intend to fight a question of law?—No, sir.

4044. Well, would you be definite then?—I think the Local Government Board ought to ascertain what is paid for the patent right, what amount, and, secondly, what that right is.

4045. The Local Government Board are to investigate patent rights for local authorities; do you really mean that?—If the Local Government Board do not do it every local authority in the country has to do it.

4046. But why, if one single local authority succeeds in a court of law would every local authority have to go and do the same thing all over again?—What would happen is what has happened, that a local authority, after it has investigated the point, finds that there is no patent right, and simply puts the tank down, while other local authorities do not know.

4047. Well, I am rather in the dark as to what you really require the Local Government Board to do?

4048. (*Major-General Carey.*) Are you referring to the Ives tank; when you are condemning these other tanks. What other tanks that have been patented are you referring to?—The Cosham tank is another tank.

4049. But do you condemn them one and all, and say that the Dortmund tank should reign supreme?—I say the unpatented Dortmund tank embodies all the points of real value in the Ives and Cosham tanks.

4050. Do you condemn all these tanks?—I say the Dortmund tank is as good as any of them, and is not patented. What I suggest would mean this: it would mean the Local Government Board obtaining an opinion from a patent agent or an opinion from such a gentleman as Mr. Fletcher Moulton.

4051. (*Sir Richard Thorne.*) And supposing the people who hold what they believe to be a patent say they do not accept such opinion as a just decision, then what would you ask the Local Government Board to do?—Then on the strength of the opinion which the local authority have got, if they are wise they will put down the tank and run the risk of an action.

4052. That is what you say they are doing now?—Those who are wise.

4053. Quite so?—But very few of them are wise, at any rate the Local Government Board might suggest to the Local Authorities the advisability of obtaining an opinion as to the validity of a patent where there is a primâ facie case against its validity.

4054. (*Chairman.*) Would you like to see this Commission suggest any standard of purity for an effluent which was to go into streams that are not used for drinking purposes or for washing purposes?—Yes, my lord, even if it were not published as a hard and fast standard, I think it would do a great deal of good if they expressed an opinion as to what a satisfactory effluent should be, and from the examination of works in actual operation I would suggest that an effluent which had more suspended matter than three parts in 100,000, and the oxygen absorbed in four hours at 80° F. of which was not more than 1·5 parts per 100,000, the albuminoid ammonia not more than ·1 to ·15, perhaps ·15, and the nitrogen as nitrates at least ·2, would be an effluent which I think every authority could obtain, and which would never cause any nuisance. The provision of a small amount of nitrate would be useful for three reasons: it would ensure that proper filtration took place; it would be a store of oxygen; and it would prevent the effluent being diluted. The general objection to adopting a standard that I have frequently heard is that authorities would dilute. For instance, they say if you adopted as your standard ·1 of organic ammonia that a local authority would dilute its effluent with water to get down to it, but if you adopted a small quantity of nitrates as a minimum it would stop them diluting, because at the same time they would be diluting their nitrates.

4055. Have you any suggestions as to standard where the sewage goes into a stream that is used for drinking purposes?—I have not dealt with that in my evidence, but what occurs to me as obviously the thing is this, that it would have to be a numerical standard such as Koch's standard of 100 in drinking waters—what the actual number should be I am not prepared to say offhand—but I should think that a numerical standard of colonies of bacteria plus a chemical standard could be worked out.

4056. I should like just to ask you a few questions connected with land treatment. You have told us of the great variety of soils, but do you think that when the land itself is frozen that any soil would answer?—Not unless it is very good land, and constantly being irrigated, as an intermittent filter not by irrigation.

4057. Well, have you ever formed any opinion as to what results land treatment would give throughout an ordinary English winter, or have you ever undertaken by continuous observation and analyses to ascertain anything of that kind?—No, except on the Burton sewage farm.

4058. And the Burton sewage farm is very peculiar, is it not?—Yes; that is so.

4059. Should you say that it was right to keep milk cows on a sewage farm?—I do not see any objection if the cows are kept up.

4060. You do not think there is danger of the spread

of typhoid fever, say, from the milk of these cows, which might possibly have access to sewage either as a liquid to drink or as a forage?—In my answer to the question whether it was right to keep milk cows on a sewage farm, I meant the cows kept constantly under cover; I meant the cows kept constantly in their cowsheds. I was thinking then particularly of the Birmingham sewage farm, where they have some 400 or 500 cows constantly under cover. I was a practitioner in Birmingham for some time. The milk from that farm was supplied to people in my own district, and I certainly should have known if there was any reason to suspect it.

4061. (*Major-General Carey.*) The cows fed from the produce on the farm?—Yes, sir.

4062. Not fed on the farm?—No, but properly kept in cowsheds provided with a proper water supply, and so on.

4063. But you do not think it would be wise to rear and keep stock on the farm?—No, I do not, sir.

4064. (*Chairman.*) Have you ever known any prejudice on the part of the public against milk that comes from a sewage farm or against the use of the produce of a sewage farm?—Take the case of Birmingham. When I lived there it was generally known who had the milk from the Birmingham sewage farm, and he was a most successful milk dealer.

4065. Do you believe that it is possible that a sewage farm can pay as a farm if it is properly used for purification?—I have no experience of my own knowledge, but I do not see any reason why it should pay any more than an ordinary farm.

4066. No, no; the question is rather whether it would pay?—I should say it would not pay so well as an ordinary farm.

4067. No?—Certainly it will not pay if you are to pay for the labour of purifying the sewage, because the sewage will have to be applied so intermittently that if you put the cost of that down—the cost of applying the sewage intermittently so as to effect purification, I feel certain it would not pay.

4068. (*Major-General Carey.*) Do you know what the profit or the loss on the Birmingham farm is?—I have not got the figures.

4069. But I mean is it a loss?—I could not say, sir. It is not a case in point, because it is insufficient at the present moment to purify the sewage.

4070. Why not; you mean that the effluent is so bad?—That the present area of land is being nearly doubled, as it is at present insufficient to purify the sewage.

4071. At all times?—I cannot say that, but it is well known that they are taking over 1,000 acres more land, and under the advice of Professor Dewar they are constructing biological filters.*

4072. (*Chairman.*) In your experience have you ever known land getting sick of sewage?—Certainly I have. I have seen land so sick that when I handed up to one of Her Majesty's judges a photograph of the farm in question he asked me if it was the lake district. The sewage would not go through the land; it simply lay about on this large surface in lagoons of sewage. The effluent simply stank of sulphuretted hydrogen. The Chesterfield farm, too, has been absolutely sewage sick.

4073. You have known land get sewage sick; have you known it get sick from raw sewage or from sewage after precipitation?—I have not known it sick from sewage after precipitation; it was from raw sewage.

4074. You have never known it sewage sick after precipitation?—No.

4075. Have you ever known the soil of an old sewage farm to have been analysed bacteriologically?—I have not, my lord.

4076. (*Colonel Harding.*) I suppose we may take it that in the absence of any experience of your own as to the treatment of crude sewage upon the filters, you are of opinion that in various forms artificial filters will give effective results in dealing with sewage from which suspended matters have been fully removed?—Yes, sir.

4077. Have you been able to come to a conclusion as to the best way of working artificial filters, whether intermittently or on the principle of a continuous dribbling through the material and a continuous aeration?—I have not had any proper comparative tests, but I am quite satisfied that the continuous dribbling is satisfactory.

4078. And you incline to the view that that is the preferable plan?—I am inclined to that view. I do not hold the view very strongly; I should like that to be the result, because I think it would be cheaper to construct works upon that principle.

4079. How far have Mr. Lowcock's filters been tried on a practical scale?—Mr. Lowcock's?

4080. Yes; in your interesting book you refer to Mr. Lowcock's filter, and give a section of it, and speak of it with some approval, but has it only been carried out on an experimental scale?—Only on an experimental scale.

4081. How large a scale?—I should say about twenty square yards.

4082. Quite a small filter?—Quite a small filter.

4083. It has not been carried out further; have you been able to form any opinion whether it is practicable to carry out on a larger scale; practicable, I mean, in regard to effectiveness and cost?—I think it is; I see no reason why it should not do.

4084. Then, as matter of fact, it has not been carried out on a practical scale?—No, sir.

4085. Then what about Mr. Lomax's system of intermittent flushes every twenty minutes that you refer to?—That has been tried on a practical scale.

4086. How large a scale?—I cannot speak from memory, but it has been tried on a practical scale at Failsworth, near Manchester.

4087. Do you know on what scale; what is the area of those filters?—Of course, this is purely from memory, but the filters are bigger than this room; each is about 36ft. square.

4088. You have no personal knowledge of them, have you?—Oh, yes; I have seen them, and analysed the effluents from them.

4089. You have seen them?—Yes, I have seen them. I should say the filters are larger than this room, and what impressed me very strongly with regard to this method of applying sewage is that I went down to the effluent drain, and I was able by striking a match to prove that the air was displaced by my match being blown out at the bottom of the filter when the sewage was flushed over.

4090. Then the incoming sewage forced the air downwards?—Forced the air downwards out at the bottom.

4091. The usual plan is to see the air bubbling up through the sewage?—Yes.

4092. In this case you say it forced the air downwards and out into the drains?—Yes.

4093. That, of course, is an intermittent system?—Yes, sir.

4094. You find that to be effective?—A very good effluent was produced, and the rate of filtration was rather excessive.

4095. (*Dr. Russell.*) I have only one question to ask with reference to Burton-on-Trent. What do they do with the sludge that is deposited in the carriers?—The sludge is dug into the land, and I certainly think that if that method of dealing with sludge is to be retained it will be necessary to have a certain limited area of land set apart which should not be irrigated.

4096. How much labour does that involve?—It does not involve any more labour, if it involves as much labour as the method of dealing with the sludge at Birmingham; it simply means that they allow the sludge to deposit where it will upon the land, and afterwards they do not irrigate that bit, and just dig it in.

4097. That is the method at Birmingham?—At Burton.

4098. I thought in your evidence you said that it was only clarified filtrate—clarified effluent rather—that reached the land, and therefore the sludge must be left in the carriers?—They are earth carriers: that is why it is.

4099. Oh, they are earth carriers?—They are earth carriers.

4100. But still it involves some labour?—Certainly it does.

4101. Do they shovel it and barrow it, or what?—No; it is simply dug in where it is. It is at places dug out and put in a heap at the side to help to dry a bit, and then it is dug in or used as a top dressing.

4102. And does it ever give rise to any nuisance?—It has not given rise to any nuisance yet.

* The area at present under irrigation is 1,180 acres. By the Birmingham, &c., District Drainage Board Act, 1897, (60 Vict. c. 46), powers were obtained to purchase 1,192 more acres, about 1,000 of which have been recently purchased.

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4103. Are you afraid of its causing a nuisance ultimately when you say "yet"?—I think that if the Corporation of Burton would set aside certain areas—long narrow areas for the sludge and not irrigate them, the system is worth considering. It is the same process of dealing with the sludge that is at work on Stratford-on-Avon. They are the only two places that I know of where such a method of dealing with the sludge goes on. At Stratford-on-Avon there is no nuisance, and it has not involved them in any difficulty whatever, but at Burton the quantity of sludge is so enormous that I should think that in time it will interfere with their levels.

4104. (*Colonel Harding*). Did you not tell us that at Burton they added 40 grains per gallon of lime?—Yes, sir.

4105. And the sludge may well be enormous; it is equivalent to the total solids in many sewages?—Yes.

4106. (*Major-General Carey.*) Have any experiments been made for treating Burton sewage in bacterial filters?—No, not at present; I do not want a note made of this if I might say it; but it is a matter of interest, that Professor Dewar who is advising them has just agreed with me to recommend an experimental biological filter. The Corporation have not adopted it, but I have no doubt they will adopt it.*

4107. With bacterial filters, I presume?—I shall recommend coal.

4108. Have any other filters been found successful in treating that sewage?—I do not think so.

4109. Do you know what proportion of brewery refuse is treated at Lichfield?—I do not know the exact proportion, but it is large.

4110. Has your attention been drawn at all to the reduction in water capacity of bacterial filters after they have been in use for some time?—I have no knowledge of my own on the subject; I have had my attention called to it.

4111. (*Sir Richard Thorne.*) You were saying just now that the bacteriological filters do not effect a large amount of bacteriological purification; would you give us the data for that; what tests you have made or known in the matter?—I base that opinion upon the Massachusetts experiments.

4112. It is not your opinion?—Not an opinion based upon my own work. Perhaps I ought not to have expressed the opinion quite so strongly as I did.

4113. It depends on whether you consider it to be true or not?—Well, it depends on what you mean by "a large amount of purification." I have not read the experiments lately, but the impressions I have is that the coarse filters, though they effected a large chemical purification, did not effect a purification of 95 per cent. of bacteria.

4114. Of bacteria that are harmless or bacteria that are harmful?—Both, sir.

4115. Is there not objection to getting out the harmless ones?—I do not know that there is.

4116. Are they not probably of great advantage?—They may be; probably they are, but I do not see how pathogenic organisms are to be got out unless you get out the whole, or a large proportion of the whole.

4117. But I suppose that you would agree that the mere question of counting colonies is absolutely valueless, is it not?—Well, I would rather drink London water with about five colonies than London water with about 2,000 or 3,000.

4118. When you are ignorant of what they are?—Yes, sir. The mathematical chances of swallowing a pathogenic organism are less.

4119. You were speaking of clay lands which were so stiff that sewage could only escape downward by cracks?—Yes, sir.

4120. What becomes of the sewage on those farms when the clay is not cracked. They were farms, you will remember, as to which you said loans had been granted?—It passes chiefly down through worm-holes.

4121. Oh, worm-holes at ordinary times and cracks when the land is dry?—Yes, except of course what is absorbed and evaporated by the plants.

5122. If we wanted to see any of that class with regard to which loans have been granted could you specify some?—Brampton and Chesterfield.

4123. Those are both in Derbyshire?—Yes, sir, both in Derbyshire; you could not have a better example.

4124. Then in those cases there *is* no purification at all?—Except what takes place by subsidence upon the surface of the land and absorption by plant life.

4125. May I ask you one further question with regard to the soils which you deem to be suitable—as you say in your book for sewage farm purposes; you mention flint and chalk?—Yes, sir.

4126. Do you know what the water companies say of the chalk ranges north and south of London?—Oh, I expect they object to sewage farms upon them, and so should I.

4127. But is there no reason for objecting to fissured chalk?—Fissured chalk?

4128. Well, chalk always has some fissures in it, and sometimes very substantial ones. My point is that you put down definitely in your book flint and chalk, as suitable for sewage farming purposes?—I was not supposing that there were any waterworks in the question, but merely dealing with various soils as media for sewage purification.

4129. Still the chalk is a great water supplying strata, is it not?—I should certainly qualify that very strongly if there were water works in the vicinity. I should certainly do that. My lord, a suggestion I should like to make is this: that when the Commission have published their report the Local Government Board should keep us up to date with regard to this question. I do not think there are any references in Sir Richard Thorne's report, nor does the Local Government Board's engineers' department publish a report upon the subject. I think there ought to be an annual reference to the subject to keep abreast of the increasing knowledge of the subject and generally up to date. We get most valuable information on most subjects from the Local Government Board, but upon this, as far as I know, they do not publish any references.

*Since giving evidence the Burton Corporation have agreed to put down a biological filter of coal.—S. B.

Appendix No. 8.

Report dated Oct. 8, 1900, by Dr. Barwise on the Purification of Sewage at the Burton Sewage Farm.

SIXTEENTH DAY.

Wednesday, 15th February, 1899.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

DR. SAMUEL RIDEAL, called in; and Examined.

4130. (*Chairman.*) You are Dr. Samuel Rideal, of 28, Victoria Street, Westminster, D.Sc. (London), Fellow of University College, London, Fellow of the Institute of Chemistry; and of the Sanitary Institute; you are the author of several books dealing with sanitary chemistry, and you have read numerous papers before scientific societies on the subject of sewage disposal embodying the results of your researches?—That is so, my lord.

4131. What is your experience of the variation in the quality of sewage?—I may give from my own analyses an example of the influence both of the time of day and the rainfall on a strong sewage from one source.

TABLE showing Influence of Rain on Quality of Sewage.

PARTS PER 100,000.

Time and Circumstances.	Flow in gallons per 24 hours.	Solids in Solution.	Cl.	O consumed.	Free NH_3	Albd. NH_3	Nitric N.	Nitrous N.
Dry weather, no rain.								
10 a.m. to 5 p.m.		77·5	12·25	7·23	3·0	1·5	None.	None.
6 p.m. to 1 a.m.	54,000	45·0	6·25	6·91	2·90	0·6	"	"
2 a.m. to 9 a.m.		34·0	4·25	5·57	0·90	0·35	"	"
Total Chlorine—41 lbs. per day.								
Heavy storm.								
10 a.m. to 5 p.m.		54·4	7·75	3·58	11·5	4·12	·056	None.
6 p.m. to 1 a.m.		45·6	5·25	2·66	3·5	1·75	·014	Trace.
2 a.m. to 9 a.m.	79,000	34·4	3·75	0·74	4·5	5·5	Trace.	Very heavy.
Total Chlorine—44 lbs. per day.								

Physical Characters.—Dry weather: Thick and fetid, fragments of paper and lumps of fæcal matter abundant.

" " Heavy storm: Turbid, yellow-brown, earthy odour.

In the morning, urine is prominent, as shown by the chloride and by other signs; later on, soapy water makes its appearance, with a white scum of fatty lime salts that tends to clog filters and leave a greasy deposit on channels; fixed alkalinity also appears, with an increase in the sodium salts; subsequently the sulphuretted odour of vegetable washings is evident, and the liquid may even become temporarily acid. The road detritus and heavier matters are usually caught in a grit chamber, while paper, string, and animal and vegetable fragments are commonly carried forward with the mixture, which rapidly becomes black, alkaline, and putrescent. The following analyses show the alteration occasioned by mere mechanical straining or filtration. They are averages of thirteen hourly samples from 6 a.m. to 6 p.m. taken from different sewers of a large town on the water closet system in 1897.

TABLE showing Variation in Quality of Sewage in different Sewers of the same Town.

Parts per 100,000.	Organic N.	Solids.	Cl.	Free NH_3	Alb. NH_3	O consumed.	Nitric N.	Nitrous N.
A.—Dissolved	7·21	94·0	20·8	6·5	3·1	5·34	·096	None.
Suspended	6·18	35				5·86		
Total	13·39	129				11·2		
B.—Dissolved	5·56	57	11·1	5·0	1·6	5·86	·12	None.
Suspended	3·71	51				9·38		
Total	9·27	108				15·24		
C.—Dissolved	7·2	72	12·7	7·0	3·65	6·59	·08	None.
Suspended	1·55	60				7·68		
Total	8·75	132				14·27		
D.—Dissolved	11·33	90	12·0	7·0	2·05	8·67	·12	None.
Suspended	1·85	45				5·28		
Total	13·18	135				13·95		
E.—Dissolved		66	10·4	5·5	1·53	5·41	·14	None.
Suspended		33				3·39		
Total	11·12	99				8·80		
Average—Dissolved	7·82	76	13·4	6·2	2·39	6·37	·11	
Suspended	3·32	45				6·32		
Total	11·14	121				13·69		

These examples show that the suspended solids contain about one-third of the organic nitrogen and half the carbonaceous matter of the sewage.

4132. How should samples for analysis be collected?—Proportionally to the flow, and not in equal quantities as is often done, *e.g.*, recent experiments at Manchester.

4133. Are you of opinion that the bacterial transformations of sewage occur in more or less distinct stages? If so, will you give us an account of these stages?—When fæcal and other solid matters are first discharged, the earliest changes must be *aerobic*, because of the free oxygen dissolved in the water and contained in the air. This effect is mainly the same as the *last* stage, *i.e.*, the organisms acting in a normal manner upon those simpler constituents like ammonia, which must obviously already exist in small quantities, and into which the process itself afterwards resolves the main ingredients of the sewage. Nitrates in small quantities are consequently often observed in discharges which are moderately fresh. As soon as the free oxygen has been exhausted, the purely oxidation changes will come to an end, and the bacteria which require air will in part disappear, and in part remain quiescent to resume their functions at a later stage. On the other hand, the anaerobic organisms will commence to multiply, the nitrate will be reduced to nitrite, and this to nitrogen, according to reactions we shall explain later, and the liquefaction and hydrolysis change will proceed. This is the condition when the sewage arrives at the works, and the first, or anaerobic, stage of the treatment proper commences. In the second stage aeration is to be encouraged as much as possible, so that the aerobic bacteria may act, and ammonia and carbonic acid be produced, with the help of some of the anaerobic forms. In the third stage with provision of a still larger quantity of oxygen, the nitrifying group will get rid of the remaining products. We may summarise the order of the changes as follows:—

	Substances dealt with.	Characteristic Products.
Initial:		
Transient aerobic changes by the oxygen of the water-supply, rapidly passing to:—	Urea, ammonia, and easily decomposable matters.	——
First Stage:		
Anaerobic liquefaction and preparation by hydrolysis.	Albuminous matters. Cellulose and fibre. Fats.	Soluble nitrogenous compounds. Phenol derivatives. Gases. Ammonia and amines. Small quantities of sulphur compounds.
Second Stage:		
Semi-anaerobic breaking down of the intermediate dissolved bodies.	Amido-compounds. Fatty acids. Dissolved residues. Phenolic bodies.	Ammonia: nitrites. Gases.
Third Stage:		
Complete aeration: nitrification.	Ammonia and carbonaceous residues.	CO_2, H_2O and nitrate.

The fermentations occurring in the hydrolytic part of the process may be chemically classified as follows:—

1. The solution and decomposition of albuminous bodies.

2. The fermentation of urea.

3. The fermentation of the amido-compounds formed from the albuminous bodies.

4. The formation of organic acids and the fermentation of their salts.

5. Cellulose or methane fermentation.

6. The fermentation of carbohydrates.

7. The formation of small quantities of sulphur compounds, like H_2S, mercaptan, etc. This, from the odour of the products, often attracts the most attention.

These, as a rule, are conducted by bacteria; moulds and yeasts not being commonly found in sewage; indeed, their presence, according to Andreasch, is distinctly prejudicial to normal bacterial action. The following is a list of many of the sewage bacteria, which have been found by various observers:—

BACTERIA OCCURRING IN SEWAGE.

L, liquefying gelatine. SL, slightly liquefying.
NL, not liquefying.

Obligatory Anaerobes:

Spirillum rugula, L (very active, spore bearing, gives rise to fæcal odour).
Sp. amyliferum (in absence of air acts as a vigorous ferment).
Bacillus enteriditis sporogenes (Klein:
B. amylobacter, L (Clostridium butyricum).
B. butyricus (Botkin), L (gives much gas).
(B. subtilis is aerobic and rapidly consumes oxygen, so is dormant in the first stage).

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Facultative Anaerobes or Aerobes:

B. putrificus coli, NL (decomposes albuminous substances with liberation of ammonia whether air is present or not.

Spirillum plicatile, serpens, undula, tenue, and volutans.

Vibrio saprophilus, aureus, flavus, flavescens, NL (in sewer mud). (Weibel).

B. mycoides, L } Produce NH_3 from nitrogenous
Proteus vulgaris, L. } organic matter, and denitrify.

B. fluorescens putridus (similar, produces trimethylamine).

B. fluorescens liquefaciens L, and non-liquefaciens NL.

Micrococcus ureæ, NL; B. ureæ, NL (convert urea into ammonium carbonate, the latter the most energetically). Flügge has also described a M. ureæ liquefaciens.

B. mesentericus L (several varieties in London crude sewage).

Proteus mirabilis and Zenkeri L.

B. megaterium L, liquefaciens L, magnus, spinosus.

Streptococcus liquefaciens coli L, and mirabilis NL.

B. saprogenes, I., II., III.; pyogenes and coprogenes fetidus.

B. acidi paralactici.

B. lactis aerogenes NL (produces CO_2 and H).

B. coli communis NL, (produces much gas, mainly H).

Cladothrix dichotoma L.

Proteus sulphureus L (produces H_2S and mercaptan).

Bacterium sulphureum L (liquefies gelatine and casein, produces H_2S: found by Sims Woodhead in Exeter sewage).

Beggiatoa alba (secretes granules of sulphur, formed according to Winogradsky by oxidation of H_2S, and finally turned into sulphuric acid by the plant).

The following forms reduce nitrates to nitrites:

B. vermicularis, liquidus, ramosus, aquatilis (grows luxuriantly in ammonia solutions), besides mycoides and Proteus vulgaris.

The following were found by Jordan in the sewage of St. Lawrence, Massachusetts:

B. cloacæ L, ubiquitus NL, reticularis SL, circulans L, hyalinus L, all reducing nitrates; superficialis SL, not reducing.

As sewage contains little or no oxygen, nearly all these species must be at least facultatively anaerobic, and the decompositions they engender are hydrolytic. Consequently it is a mistake in the first stages to introduce air, which merely hinders the anaerobic changes, and at this point only weakly encourages the aerobic ones. An attempt to induce early nitrification before solution is effected, results in the production of nitrites and not nitrates.* The some non-recognition of anaerobic liquefaction leads to the difficulty with the solids blocking the filters, and to the compulsory resort to screens, sedimentation, or even to an idea of preliminary precipitation, all of which produce their equivalent of sludge. During the "resting full" period of the filters the changes are really anaerobic, during emptying and resting empty the aerobic bacteria are at work. Therefore if sole dependence is made on filters, the process is a mixed and variable one, and the result is shown in deficient nitration. In sewer mud, five species of vibrios have been defined. They do not liquefy gelatine, and their action is probably on the carbonaceous vegetable matter.

The putrefactive fermentation of albuminous bodies is caused by a large number of species. The first action is parallel to ordinary digestion, that is the so-called peptonisation, or conversion into a soluble form. The peptones are then split up, amido-acids like leucin, tyrosin, etc., are formed, together with a number of substances of the aromatic group.† The amido-acids further break up into fatty acids and ammonia. Tyrosin yields indol, skatol, phenol, and acids related to benzoic (Spirillum rugula and the B. coprogenes group develop a strong fæcal odour, probably owing to this reaction).

The breaking up of organic acids is described in the following table, adapted from an admirable summary of the varieties of septic fermentation, by Dr. E. Herfeldt, of Bonn. (Centralblatt fur Bakt., Jan. and Feb., 1895; J. Soc. Chem. Ind., May, 1895.)

* Bacillus mycoides, liquidus, vermicularis, ramosus, cloacæ (Jordan) aquatilis, and others, powerfully reduce nitrates to nitrites, and account for the absence of nitrates in sewage.

† Oscar Emmerling found that Streptococcus longus, in liquefying fibrin, produced peptones, and then ammonia, mono- and tri-methylamine, tyrosine, leucine, fatty acids to caproic (except valeric), succinic, and a-collidine or pyridine derivative. (Berichte, 1897, XXX., p. 1868).

TABLE OF FERMENTATIONS OF ORGANIC ACIDS.

(For simplicity the sodium salts are taken, though the lime salts are rather more fermentible.)

Salt fermented.	Cause of Fermentation.	Products.
Formate	Bacteria and moulds	Acid sodium carbonate, $NaHCO_3$, Carbonic acid and hydrogen.
Acetate	Bacteria and moulds	Acid sodium carbonate, $NaHCO_3$, Carbonic acid and methane, CH_4.
Lactate (Undergoes four different fermentations.)	Thin baccillus (Fitz) Other species of bacteria; short aerobic butyric bacteria (Fitz).	1. Propionic acid, and as bye-products, acetic and succinic acids and alcohol. 2. Propionic and valerianic acid. 3. Butyric and propionic acid. 4. Butyric acid and hydrogen.
Malate (Different fermentations.)	Bacteria (not described) "Thin bacilli."	1. Chief product, propionic acid; bye-product acetic acid. 2. Chief product, succinic acid; bye-product acetic acid. 3. Butyric acid and hydrogen. 4. Lactic acid and CO_2.
Tartrate	Different species of bacteria.	1. Chief product, propionic acid; bye-product acetic acid. 2. Butyric acid. 3. Chief product, an acetate; bye-products, alcohol, butyric and succinic acids.
Citrate	"Small, thin bacilli"	Acetic acid in large quantities, with small quantities of alcohol and succinic acid.
Glycerate	Micrococci Medium-sized bacilli.	1. An acetate, with small quantities of succinic acid and alcohol. 2. Formic acid, with some methyl alcohol and acetic acid.
		(Under active microbic fermentation all eventually pass into CO_2 and H, or CH_4. The CO_2 is partly free, and partly as bicarbonate of the base. Acetic acid is generally the penultimate product, therefore the common production of methane. Any amides of the acids are hydrolysed, with liberation of ammonia).

4134. What is the advantage of the first or anaerobic stage?—I have always been of opinion, and have often urged on previous occasions, that the anaerobic change is an integral part of the preparation, and that the neglect, and even avoidance of it, has been a frequent cause of failure. As Rudolph Hering aptly remarks: "The aerobic process, when applied to organic matter in suspension, is slower than the anaerobic process. It takes a long time for solid particles of organic matter to disappear as such, when the conversion depends on the oxygen contained in the water. It takes a short time when it is brought about by anaërobes, which produce conditions causing liquefaction. The reverse seems true in the case of organic matter in solution, because the aerobic bacteria, and conditions favouring a thorough aeration of liquid sewage, will remove a much greater amount of organic matter from the water in the same time than if it is left to the action of anaerobes." Therefore the processes should be properly and systematically conducted in natural sequence. Any mixing or confusion in the order, any artificial interference, or attempt to work distinct reactions simultaneously in the same receptacle, will lead to uncertainty and irregularity in the results.

4135. Have you an example of the changes that are effected anaerobically in practice?—Yes; with the Exeter tank in 1896 I obtained the following results:—

	Total Solids in solution.	Oxygen consumed.	Free NH_3.	Alb. NH_3.	Nitrite.	N as Nitrate.	Total N.	Organic Nitrogen.
Raw Sewage, Nov. 3, 4.	46·8	6·56	3·6	1·40	0·0	0·0	7·4	4·4
Tank Effluent, Nov. 4, 5.	48·6	4·32	4·9	0·64	Trace	0·04	6·24	2·2

From the above results it will be seen that the changes produced by the passage of the sewage through the tank may be summarised as follows:—

1. A marked increase in the total solids in solution or fine suspension.
2. A reduction of about 33 per cent. of the organic matter as measured by the oxygen consumed.
3. An increase of about 33 per cent. in the free ammonia.
4. A reduction of about 54 per cent. in the organic or albuminoid ammonia, or 50 per cent. in the organic nitrogen.
5. A slight production of oxidised nitrogen and disappearance of a small amount of the total nitrogen.

It is therefore evident that the septic tank by means of its bacteria, enzymes, or spontaneous chemical decomposition, materially alters the composition of the raw sewage. The increase in the total solids points to a solvent action of the water on matter in suspension, and this may be due to a digestive or to a purely physical process, but the marked disappearance of organic matter and transference of the nitrogen from the organic condition to that of free ammonia is undoubtedly due to bacterial influences. The above changes should be capable of being confirmed by (1) Evidence of the production of gaseous carbon compounds, either oxidised as carbonic acid, or as hydrocarbons, and (2) Evidence of the production of nitrogen in a gaseous form, either as free nitrogen, lower oxides of nitrogen, or possibly ammonia which has escaped solution. The correctness of this was proved by subsequent experiments which established the fact that the dissolved carbonic acid was increased in the effluent, and that carbonic acid gas, nitrogen, marsh gas, and hydrogen existed in the air in the upper part of the tank, which was also found to be entirely deprived of its oxygen. The raw sewage and the tank effluent were also proved to be devoid of free dissolved oxygen, so that although atmospheric oxygen might leak into the tank, I am of opinion that the amount of direct oxidation in the tank must be very small and that the oxidised compounds produced must be formed from the dissolution or hydrolysis of oxygen-containing organic compounds. Two analyses of the gas obtained (1) from the slotted pipe, and (2) from below the surface of the liquid in the tank are given below; the second sample burnt freely, and neither sample contained any oxygen:—

	Per cent. by Volume. I.	II.
Carbonic Acid	0·3	0·6
Methane	20·3	24·4
Hydrogen	18·2	36·4
Nitrogen (by difference)	61·2	38·6
	100·0	100·0

Several determinations of the amount of carbonic acid in the gases of the septic tank showed that from 0·54 to 0·81 per cent. was present, or about fifteen times that in the outside air. As the tank was not constructed in such a way as to allow the gases produced to flow uniformly out of the tank, the absolute amount of gas produced per 50,000 gallons of sewage per twenty-four hours could not be gauged, but it is easy to see that with diffusion taking place, the total loss of carbon and nitrogen per day may be very considerable. A further and more distinct proof of the large amount of organic carbon which disappears in the tank is given by the fact that the dissolved carbonic acid was greater in the tank effluent than in the raw sewage. Thus the carbonic acid produced in the tank effluent was determined and found to average 8·8 parts of carbonic acid per 100,000, or 12lbs. of carbon per 50,090 gallons discharged. As on this particular day 62,238 gallons discharged, the above amount of carbon should be increased to about 15lbs. to represent the loss of carbon on this day.

TABLE showing Amount of Carbonic Acid formed in Tank.

In ccs. N/10 Acid per litre				Amount Formed.
No. of Sample.	Sewage.	No. of Sample.	Effluent.	
	93·0 ?	5	92·0	0·0
2	24·2	6	92·0	67·8
3	38·0	7	94·4	56·4
4	60·0	8	105·6	45·6
			Average	42·45

Amount of Carbonic Acid Gas in the Air of the Septic Tank.

On November 14th samples of gas were aspirated for analysis from about 4 inches above the level of the liquid in the tank.

	Time.	Volume containing equal weights of CO_2.	Percentages of CO_2.
Plug No. 1	11.25 a.m.	1·8	0·54
„ 2	11.50 „	1·2	0·81
„ 3	12.10 p.m.	1·4	0·70
„ 4	12.20 „	1·7	0·57
„ 5	12.30 „	1·3	0·75
Air	11.15 a.m.	24·4	0·04

Average amount of carbonic acid in air of tank = 0·67 %.

The presence of these appreciable quantities of gases containing carbon in the tank and tank effluent undoubtedly proves that considerable purification of the sewage in the tank takes place. Since the date of the above experiments the tank has been made air-tight, and the gases formed have been led off by a pipe and ignited. So that it would be possible for the combustible gases produced to be regularly burnt if a gas holder to regulate the pressure were used. As the amount of increase in the total solids in the first set of experiments might have been due to the suspended matters in the samples examined—although one would have anticipated more suspended matter in the raw sewage than in the effluent after sedimentation had taken place—a further new series of experiments was started on November 13th, and the samples analysed after filtration. The mean results cal-

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culated to a chlorine content of 7 parts per 100,000 are as follows:—

	Total Solids in solution.	Oxygen consumed.	Free NH_3.	Alb. NH_3.	Nitrite.	N as Nitrate.	Total N.	Organic Nitrogen.
Filtered Samples—								
Raw Sewage, Nov. 13, 14.	55	3·61	8·5	4·3	Trace	0·02	12·82	5·8
Effluent, Nov. 14, 15.	59	2·73	11·2	2·66	Trace	0·022	14·92	5·7

It will be seen that the above results give the same general conclusions as were arrived at from the former series, viz., an increase in the total solids, 25 per cent. of organic matter destroyed, an increase of 33 per cent. in the free ammonia, and a decrease of 38 per cent. in the albuminoid ammonia. The total nitrogen, however, in this series shows a slight increase due to the larger amount of ammonia found in the effluent, or summarising—

	Purification effected by Tank	
	Oxygen consumed.	Albuminoid ammonia.
1st Series - - - -	33	54
2nd Series - - - -	25	38
Mean - - -	29%	46%

The Rivers Pollution Commissioners, after an examination of the various processes of chemical precipitation then known, came to the conclusion that the average amount of purification was 28·4 per cent. Org. C. and 36·6 Org. N.

The septic tank seems therefore to effect as much purification as an average chemical precipitation process, or as slow upward filtration. It will be further noted that both sets of experiments show an increase in the total solids in solution of from four to eight per cent., and this can only be explained on the hypothesis that the solid fæces and other matter in suspension pass into solution in the septic tank.

Taking the population as 1,500, the weight per annum of solid fæces may be estimated as 975 cwt., containing 1·5 cwt. of organic nitrogen, whilst 127·5 cwt. of organic nitrogen will exist in the corresponding urine. These quantities correspond to a daily production of 300 lb. of solid fæces, containing 4·2 lb. of nitrogen, together with 34·5 lb. of dissolved nitrogen, chiefly in the form of urea, which on 50,000 gallons corresponds to 60 parts of solids per 100,000, containing 0·84 parts of nitrogen per 100,000, associated with 6·9 parts of dissolved nitrogen and 4·6 parts of chlorine per day.

Solid fæces contain 75 per cent. of water, and therefore the possible weight capable of increasing the total solids in solution would be 75 lb. per day, or 15 parts per 100,000. When it is remembered that at least 15 lb. of carbon are lost per day, as carbonic acid, or 3 parts per 100,000, or say 6 parts of organic matter, this with the 3 parts dissolved in the effluent account for 9 out of the 15 parts of solids entering the tank in suspension, excluding any estimate of the considerable quantities of marsh gas, hydrogen, and nitrogen which are evolved as gas.

The 300 lb. of solids daily may be estimated as having a volume of 1-7th cubic yard, and consequently, if no allowance be made for any dissolution, the minimum time required for this quantity to fill up the septic tank would be about three years. The experience of Mr. Scott-Moncrieff with his cultivation tank and of Mr. Cameron with his experimental septic tank, has been that after long periods of working, the small quantity of residual substance consists of a finely divided inert matter, which seems allied to humus and peat, and is probably similar to the final nitrogenous compound noticed by Adeney in his experiments on sewage, and which seems necessary for the subsequent nitrification process.—(Adeney, Proc. Roy. Soc. Dub., Sept., 1896.)

4136. If no direct oxidation occurs in the first part of the process, what is the source of the energy that occasions the decompositions?—In these decompositions by the agency of water and bacteria alone, or *hydrolytic* changes, I have found that there is a distinct evolution of heat, small in amount, and almost imperceptible in the bulk of water, but sufficient to continue the re-action, which is commonly known therefore as *exothermic*, or, containing within itself the conditions of its own propagation. This can be seen by a calculation of the thermal equivalents involved in the equations. Thus in the case of *urea*:—

$$CO(NH_2)_2 + H_2O + Aq = CO_2 + 2\,NH_3Aq$$

Heats of formation: $+77{\cdot}5$ (Stohmann) $+68{\cdot}4$ (liquid) $+97{\cdot}6$ (gas) $2\times(+20{\cdot}4)$ (in solution)

$145{\cdot}9$ $138{\cdot}4$

but the 2 NH_3 and CO_2 neutralize one another, resulting in a further evolution of about 20 units.

Hence
145·9 must be absorbed while 158·4 must be evolved, giving a balance of 12·4 units evolved.

[The units are kilogram-centigrade, and the substances are taken in gramme-molecules.]

Cellulose.

$$C_6H_{10}O_5 + H_2O = 3\,CO_2 + 3\,CH_4$$

Heats of formation: 245 68 291 $49{\cdot}5$

Heat absorbed 313 Heat evolved 340·5
Evolution of heat 27·5 units.

[I have calculated the heat of formation of cellulose thus:—
Complete combustion of 6 C and 10 H to CO_2 and water:

$$6\,C + 5\,H_2 + O \text{ in excess} = 6\,CO_2 + 5\,H_2O$$

6×97 $5\times68{\cdot}4$

924 units

Combustion of cellulose $C_6H_{10}O_5$ gives 678 units (Stohmann).

$924 - 678 = 246.$]

Albumin.

Berthelot and André (Chem. Soc. Abstracts, 1890, p. 937) state that one gramme of albumin dried at 100° C. gives 5,691 calories (gram. centigrade units).

Hence $C_6H_{13}N_3O_5 = 185$ of albumin give $185 \times 5{,}691 = 1{,}052{,}835 = 1{,}053$ kilogram units.

We must first calculate from this the heat of formation of albumin.

* $(8\,C + 13\,H + 2\,N + 3\,O)$ burnt $= 8\,CO_2 + 6\,H_2O + N_2 + H$

8×97 6×68

$776 + 408 = 1{,}184$

Hence heat of formation = 1,184 − 1,053 = 131 units.

Now, taking a simple anaerobic change:—

$$4\,C_6H_{13}N_3O_5 + 14\,H_2O = 4\,N_2 + 19\,CH_4 + 13\,CO_2 + 4\,H$$

Thermally 4×131 14×68 $19\times16{\cdot}5$ 13×97

$524 + 952$ $314{\cdot}5 + 1{,}261$

1,476 absorbed 1,575·5 evolved

giving a balance of 1,576 − 1,476 = 100 units evolved.

*** Exothermic.

It is curious that the percentage of the heat in the products which is evolved is in each case nearly the same:—

	Heat in Products.	Heat Evolved.	Per cent.
Urea - - -	158·4	12·4	8
Cellulose - -	340	27·5	8
Albumin - -	1,575	100	7

These enzyme re-actions follow the ordinary chemical law of going in the direction of an evolution of heat. They occur at atmospheric temperature, and it has been pointed out by Van t'Hoff that the lower the temperature the more nearly will Berthelot's law of maximum work be obeyed.

4137. What changes take place in the liquefaction of gelatine?—With a strictly aerobic organism like *B. prodigiosus* the liquefaction is very slow. With a facultative anaerobe like *B. fluorescens liquefaciens*, which is common in sewage, I found the following changes:—A number of flasks were inoculated with this organism, the contents being analysed after one day, when only a superficial liquefaction of the gelatin had taken place; two days, when about half had been liquefied; three and a-half days, when the liquefaction of the gelatin was quite complete; and finally after sixteen days.

* I have left out one hydrogen atom in this calculation, because in the enzyme reaction one hydrogen per molecule of albumin is set free.

The following is a tabulated summary of the results obtained :—

Calculated as Grammes of Nitrogen per 100 c.c.

Incubated at 20° to 21° C.	Total Nitrogen.	Gelatin and Albumoses.	Albumoses.	Ammonia and Volatile Bases.	Bases and Extractives.	Peptone N. unaccounted for.	Gelatin.	Albumin and Cellulose.
Blank (i.) - -	1·242	1·109	0·514	0·003	0·061	0·069	0·595	
„ (ii.) - -	1·246	—	0·528	0·004	—	—	0·581	
B. prodigiosus 14 days	1·232	1·024	0·409	0·049	—	—	0·615	
B. fluor. liquefaciens, 1 day.	1·33	1·141	0·402	0·028	—	-	0·739	
B. fluor. liquefaciens, 2 days.	1·256	0·682	0·297	0·045	0·105	0·424	0·385	
B. fluor. liquefaciens. 3½ days.	1·267	0·242	0·135	0·063	0·486	0·476	0·107	
B. fluor. liquefaciens, 16 days.	1·26	0·216	0·081	0·168	0·742	0·124	0·135	0·01

It will be noticed from the analysis of the blank that the original dry gelatin contains roughly 50 per cent. of matter precipitable by Stutzer's reagent, so-called albumoses. In the early stages these albumoses seem to be first attacked by the organism ; but subsequently their decomposition proceeds at an equal rate with that of the true gelatin.

A notable feature in this research is the small production of ammonia and volatile bases, in view of the fact that substances such as trimethylamine, indol, and skatol have been generally stated in analyses by other observers to be constant accompaniments of the liquefaction of proteids. That this is not accounted for by the volatilisation of such bodies during the incubations is proved by the comparative absence of odour and of strong alkaline reaction in the air of the flasks, and in such loss not being indicated by the total nitrogens. Previous investigations have, however, been conducted with "nutrient gelatin," containing other proteids. The quantity of ammonia produced is insignificant, amounting, even after sixteen days' incubation with *B. fluorescens liquefaciens*, to only 0·168 gramme of nitrogen per 100 c.c., corresponding to 0·204 gramme of ammonia.

The figures for the nitrogen unaccounted for, which would be almost entirely peptones, are very interesting. The original gelatin solution containing 0·069 gramme per 100 c.c., this gradually increases as the liquefaction proceeds, until, with *B. fluorescens liquefaciens*, it reaches the maximum figure of 0·476, when the medium is just entirely liquefied, and then diminishes, after sixteen days, to 0·124, showing that the bacillus, after bringing about the decomposition of nearly all the gelatin and albumoses, subsequently attacks the peptone, which has meanwhile been produced, with a corresponding increase of bases and extractives soluble in alcohol.

4138. Can the enzymes act without the bacteria?—In order to ascertain whether an enzyme is capable of liquefying the gelatin without the aid of bacteria, a large quantity of gelatin medium was inoculated with *B. fluorescens liquefaciens*, and incubated at 20° C. After about five days, when the culture was entirely fluid, some of it was filtered, by a vacuum, through a Pasteur candle into a filtering flask containing 100 c.c. of 10 per cent. gelatin that was quite sterile. When about 10 to 15 c.c. of the culture had passed through, the filter was removed, the neck of the flask plugged with cotton-wool, and the gelatin warmed to 30° C., so as to be able to mix the filtrate uniformly with the gelatin solution ; it was then allowed to set quite firmly, and incubated at 20° C. As after a few hours the gelatin was not quite solid, it was removed from the incubator and kept in a room at about 10° C. In twenty-four hours the contents of the flask were semi-liquid, and after thirty-six hours quite liquid. It was proved to be sterile by microscopical examination and by attempts at subculture. The liquid did not smell putrid, and was not fluorescent ; except that it was liquid, it appeared the same as the original gelatin solution. The contents of the flask were then analysed with the following results, calculated into grammes of nitrogen per 100 c.c. :—

Total Nitrogen.	Gelatin.	Albumoses.	Ammonia.	Bases and Exactives.	Peptone.	Vol. Org. Acids.
1·282	·359	0·21	Nil.	0·469	0·174	Nil.

The liquid was tested for the presence of peptone by dialysing a portion, and adding caustic soda and copper sulphate to the dialysate, when a strong biuret reaction was obtained ; with the original gelatin solution simi arly treated there was no reaction. That an enzyme is produced by *B. fluorescens liquefaciens* was further confirmed by repeating the above experiment on a 15 per cent. gelatin containing Pasteur's solution as before, when it was found to be liquefied in twenty hours at 17° to 18° C.

4139. Should we, therefore, attempt to use separate cultivations of individual bacteria?—The phenomenon of *symbiosis*, that is, when one or more kinds of bacteria act together, and effect decompositions which neither of them could separately, shows that it is not necessary to aim at securing individual species, which, indeed, would be impossible in practice, if the complexity of the flora of sewage be considered. If, however, successive zones or habitats be arranged under slightly varying circumstances of aeration or otherwise, groups of species will establish themselves to the exclusion of others, and sewage passing through will find itself exposed to a natural cycle of change. Such an arrangement takes place in the top and bottom layers of the septic tank, and still more in the "bacteria tanks" of Scott-Moncrieff, where the stones become coated with zooglœa layers of different organisms at successive points. The same system he carries out further in the third stage in his oxidising filter.

4140. Is there any chance of the products of the fermentations bringing the process to an end?—As regards mass action, and the hindering of a reaction by the presence of the product of an enzyme change, with the possibility of attaining a point of equilibrium between a direct and inverse change, the work of Hill (J. C. S., Aug., 1898) seems to be decisive. As a representative instance he takes the conversion of mattose into glucose by maltase, an enzyme from yeast. With a 40 per cent. solution he shows that equilibrium is reached when 84 per cent. of the sugar is maltose and 16 per cent. glucose.

$$\begin{matrix}\text{Maltose} \\ 84\%\end{matrix} \underset{\longleftarrow}{\overset{\longrightarrow}{\rightleftharpoons}} \begin{matrix}\text{Glucose} \\ 16\%\end{matrix} \Big\} \text{in 40\% solutions.}$$

In weaker solutions the equilibrium point for maltose increases, so that in a 2 per cent. sugar solution, it is almost completely converted. In a solution so dilute as a sewage the influence of the products would hardly be felt, so that the enzyme changes would proceed to completion. Still, the action is more energetic when the products are removed as formed, and the bacteria are supplied with fresh food. In nitrification the solution must not be too strong, nor too alkaline. Warington found that a 12 per cent. solution of urine was the highest strength nitrifiable and that the maximum alkalinity corresponded to 36·8 pts. per 100,000 of N. as ammon. carbonate, equal to 44·6 parts of ammonia. These are strengths which only under special circumstances would be approached in sewage. In the runnings from urinals, stables, etc., dilution would be necessary.

4141. The processes should therefore be worked continuously if possible?—Yes, the correct method of working is a *continuous* process in the three stages I have indicated ; *first*, of anaërobic liquefaction, or hydrolysis ; *second*, of partial aërobic change ; *third*, of full aeration with nitrification. In methods involving a "resting full" and "resting empty" period, there is alternate inversion of bacterial action between aërobes and anaërobes, with a disturbance of both, necessitating prolonged periods of rest. As an illustrative experiment I may quote some determinations I made at Exeter in 1896 of the amount of carbonic acid produced in an empty filter.

On November 12th, "compo" tubes were sunk to different levels in Filter No. 2, which had been in constant work for several days, and the gases aspirated for analysis two or three hours after the last discharge.

— —	Air.	Tube 1, 18 in.	Tube 2, 36 in.	Tube 3, 54 in.
Per cent. of Carbonic Acid by Volume - - - -	0·04	0·375	0·98	0·75
Relation to Volume in Air -	1	9·4	24·4	18·8

Assuming the air in each empty filter to contain 1 per cent. of carbonic acid, we have 80 gallons of carbonic acid in each filter, or about 400 gallons produced per day. The weight of organic carbon destroyed per day in this way is therefore about 2½ lb. No experiments were made to determine the amount of dissolved carbonic acid produced in the filters, but this must be considerable. I have

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shown by curves the variation in the amount of nitric nitrogen in the filtrate. A copy of the curves I now hand in. After a period of long rest, the greatest amount of nitric nitrogen makes its appearance in the first runnings, showing that it is during the period of rest that the nitric acid is formed. Analyses of the liquid rising in the "wells" on filling a filter when the residual liquid is being displaced, show nitric nitrogen of from three to five parts per 100,000 in many instances. During the "resting full" period, on the other hand, the action must be mainly anaërobic.

4142. Do these changes always go on in a natural order of sequence?—No; it is well known that in a mixture of immense numbers of species, some of them are crowded out, are not able to act, and will finally disappear. Such is the fate, as a rule, of pathogenic organisms, which preferably grow at blood heat, and do not find themselves under favourable conditions at low temperatures, and among a swarm of competing others. It has been already pointed out that in ordinary bacteria beds these reactions are somewhat fortuitously reversed and confused, according to the periods of filling or rest, the fault being caused by mixing all the different bacteria in one or two large filters.

4143. You have made a chemical examination of the constituents of the Exeter tank effluent, and found many of these chemical compounds?—Yes, the following is a summary of the results I have obtained:—

EXETER TANK EFFLUENT, Nov. 3, 1898.

Sewage odour not strong; no free H_2S; some black deposit; supernatant liquid nearly clear and of a slight brown tint.

1. *Alkalinity, distribution of Nitrogen, and examination of the volatile bases.*

Total alkalinity, 100 c.c. = 6·0 c.c. decinormal acid.
Fixed " " = 2·5 c.c. " "
∴ Volatile " " = 3·5 c.c. " "
= 5·95 pts. free NH_3 per 100,000.

By Nessler test in the original, the actual free NH_3 was 4·6 pts.

Therefore in the evaporation there was some decomposition of albuminous or amido-matters with liberation of ammonia, causing a reduction in the amount of free alkalinity.

Therefore the free ammonia estimated by distillation would be too high, and the albuminoid too low, as I shall have further occasion to remark in speaking of processes of analysis.

Organic nitrogen (Kjeldahl) =	1·98 pts.
Nitrates - - - - -	None.
Nitrites - - - - -	Trace.
Nitrogen as ammonia - -	3·79
Total nitrogen -	5·77

To further examine the 4·6 parts of apparently free ammonia, it was turned into a hydrochloride and fractionated. The composition found was:

Real ammonia, NH_3 - -	3·48 pts.
Methylamine, CH_3NH_2 -	0·844
Trimethylamine - - -	Traces.
	4·324

2. *The Solids.*

Twenty-one litres of the nearly clear liquid was distilled. (Distillate examined for volatile matters: ammonia, methylamine, trace trimethylamine, indol or skatol, small quantity of a sulphuretted volatile compound related to the mercaptans).

See further, volatile bases.

Boiled down to 1 litre and allowed to stand, a brown precipitate separated. A separate examination was made of:

(*a.*) Mother liquor; organic acids, fixed bases, neutral bodies.

(*b.*) Insoluble precipitate.

The amounts of the solids per 100,000 were:—

Organic matter, soluble - -	15·43	
" " precipitated -	2·15	
Total organic solids - - -		17·58*
Sodium chloride (6·2 pts. Cl) -	10·20	
Other inorganic matter - -	10·22	
Total inorganic solids - - -		20·42
Total solids - - - -		38·00

* These included a large amount of undefined amorphous bodies often classed as "extractives," some of them derived from the colouring matters of urine and fæces.

3. *Fixed Bases or Ptomaines.*

The residue of 21 litres—from which had been separated (1) volatile matters, basic, neutral, and acid—(2) neutral bodies soluble in ether: was alkalized and extracted with ether. The product was an obscurely crystalline white substance, weighing ·0242 gramme (= 0·115 parts per 100,000), inodorous, sparingly soluble in water, alkaline. For neutralisation it required 0·3 c.c. of $\frac{N}{20}$ acid = 1·43 c.c. per 100,000.
= 0·72 c.c. of decinormal acid.

[To give an idea what this means, if the base were guanidine, C (NH) $(NH_2)_2$, molecular weight 59, 1 cc. $\frac{N}{10}$ acid = ·0059 grm. guanidine.
= ·00425 grm. in 21 litres = 0·0202 pts. per 100,000.
Probably the main part of the base has a higher molecular weight, or is only weakly alkaline.]

4. *Other Compounds.*

Among the other substances detected were a white, waxy, odorous body, volatile with steam and soluble in ether, neutral: probably indol or skatol.

Leucine and xanthine were found, but no tyrosine.

Phenol was present. No uric acid, peptone, or sugars were discovered.

5. ORGANIC ACIDS.—(Exeter tank effluent, 21 litres).

I. As present in the soda salts soluble in water.

A. Fixed acids soluble in ether:—

	Grms. in 21 Litres.	Pts. per 100,000.
Insoluble in water:—		
Contained oleic acid - -	·056	0·267
Soluble in water:—		
Contained phenylacetic and probably lactic (no butyric in this portion).	·060	0·285
		0·552

B. Volatile fatty acids:—

Na salts distilled with H_2SO_4, fractionated, the fractions converted into Ba salts.

Fraction.	Weight of Ba Salt.	% Ba.	Calculated % of Acetate.	Weight of Fatty Acids.	Calculated Acetic.
	Volume.				
α	110 cc.	·2595	46·6	26·4	·1405	·0871
β	70 "	·1506	47·5	35·7	·0802	·0286
γ	102 "	·2475	49·7	58·4	·1260	·0736
δ	100 "	·0767	46·4	26·2	·0416	·0109
ε	103 "	·0864	48·9	—	·0490	—
ζ	40 "	·0310	27·7	—	·0225	—
			Total weight of Volatile Acids.	·4598 = 2·19 pts.	·1502 = 0·71 pts.

Which gives a probable composition in pts. per 100,000:—

Butyric Acid - - - -	1·373
Acetic " - - - -	0·710
Phenylacetic Acid - - -	0·107
	2·190

[% of Ba:—

Ba acetate - - -	53·72
" butyrate - - -	44·05

Acetic and butyric were proved in fractions, α, β, γ, δ.
ε seemed to be almost entirely butyrate.
ζ gave a strong reaction for phenylacetic, but seemed also to contain some butyrate.

II. As present in the lime and iron salts precipitated on boiling.

	Pts.
C. *Fixed.*—Insoluble fatty acids of low melting point including caproic.	0·28
Lactic acid.	0·006
	0·286

D. *Volatile.*—Had a smell like formic acid mixed with acetic and contained some insoluble waxy matter.

4144. Does not the presence of grease cause a considerable difficulty?—Soap-suds and greasy matters give rise to considerable trouble in the mechanical treatment of sewage. At Bradford the refuse of wool-scouring has been the chief difficulty for years. The sewage has been precipitated chemically by ferric sulphate, but in the addition to the large quantity of chemicals required, and the unsatisfactory character of the effluent, the very large quantity of grease in the sludge obstructs the filter presses, and renders it impossible to reduce the water below 95 or even 98 per cent., which not only increases its weight and bulk, but also the difficulty of drying. In a bacterial tank the grease is first emulsified by the ammonia. There are several bacteria that attack fats in presence of nitrogenous substances (Sommaruga, Zeits, Hyg., xvii., 441), breaking them up into simpler acids of the fatty series, like acetic and butyric, which in their turn are finally resolved into CO_2 and H. Many common moulds also act on fats, notably the ordinary green mould, Penicillium glaucum, which Hanriot (C.R. 1896, *123*, 753) found to contain an enzyme "lipase," beside emulsin and other ferments. Moulds are not commonly present in the anaërobic stage, but occur in the second, or limited aeration. Ritthausen and Baumann found that a great destruction of fat occurred by the action of moulds and bacteria in a substance containing proteids as well.

4145. What evidence is there as to the breaking down of vegetable matters in a bacterial tank?—As to the solution of cellulose and fibrous matters, Mitscherlich in 1850 proved that cellulose was dissolved by fermentation, and Van Tieghem in 1870 described the most active organism as *B. amylobacter*, anaërobic, and derived principally from the intestines of animals. Tappeiner fermented cotton-wool and paper-pulp in a weak nitrogenous solution, and obtained CO_2 and methane in neutral, and CO_2 and H in alkaline solution. Hoppe-Seyler in 1886 found only traces of soluble residues, and concluded that at first a soluble carbohydrate was formed by the action of water, and that this was then split up into carbonic acid and methane –

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6$$
$$C_6H_{12}O_6 = 3CO_2 + 3CH_4$$

If more water took part, less CH_4 and more H would be obtained.

Van Senus in 1890 proved the fermentation of fibre to be anaërobic, that it was occasioned by a symbiosis, or concurrent action of *B. amylobacter* with *butyricus* and other organisms, and that gaseous products of the above character finally remained. He isolated an enzyme which dissolves fibre, and also a group of these resolving bacteria from mud, stomach contents, and decaying vegetable matter.

In laboratory experiments with different kinds of cellulose, paper, cotton-wool, etc., in water inoculated with sewage organisms, I have observed gradual liquefaction with the production of inflammable gases.

The changes occurring in silos and in manure heaps may be noticed as examples of the anaërobic breaking down of cellulose and fibrous matters.

The smaller remains of vegetable matter which pass down sinks, occasion considerable nuisance when an attempt is made to remove them by screens or on the top of a coarse filter. They act objectionably in three ways:—

1. They set up acid fermentation and corrode iron;
2. Many of them, like the cabbage family, contain sulphur compounds and evolve very offensive odours;
3. They form a pulp which blocks the strainers.

Under anaërobic conditions in a closed space they rapidly rot away and disappear, their pectose first dissolving, and then their cellulose, while the ammonia takes up the acids.

Fermentation of Other Carbohydrates.

Starch, different sugars, and gummy substances, undoubtedly enter into sewage. But their hydrolysis is so rapid, that very little trace of them is found after a short period. Those fermentations, like the alcoholic, which are occasioned by higher fungi like yeasts and moulds, do not present themselves. The changes are mostly *lactic* by *B. acidi lactici*, or *butyric*, by *Clostridium butyricum* or *Bacillus butyricus* (both anaërobic), giving, besides the respective acids, carbonic acid, hydrogen, and water.

4146. Can you tell us something as to the odorous compounds that are evolved from sewage?—These are mainly of two types, amines and sulphur compounds. The lower amines smell like ammonia, and are commonly reckoned as such, as I have observed in the Exeter analysis, where I found monomethylamine. Trimethylamine has a fishy smell, which is very marked in some sewages. *B. ureæ*, *B. prodigiosus*, and *B. fluorescens putridus* develop this compound during putrefaction; amylamine and others are also found. The chief importance of the group lies in

1. Their volatility and odours;
2. Their removing carbon as well as nitrogen;
3. The toxic nature of some, by which they hinder the subsequent nitrification. Therefore:—

(*a*) The preliminary liquefaction should be conducted in a closed chamber;

(*b*) The amines must be removed by a nitrous or other oxidation in the second part of the process before reaching the nitric organisms.

The same remarks apply to:—

The Sulphur Fermentation.—Dr. Sims Woodhead found *Bacterium sulphureum* in the Exeter tank. It liquefies gelatine, casein, and other albuminoids, and produces sulphuretted hydrogen. Several observers did not, however, find H_2S in the tank gases. I have found that a mercaptan (methyl hydro-sulphide) and other ethereal compounds are undoubtedly present in small quantities. They are very soluble, and easily oxidisable.

Most of the sulphur, however, enters into combination with the iron present in the sewage, forming insoluble ferrous sulphide, and giving a black colour to the suspended matter. When the black matter is treated with acids, sulphuretted hydrogen is evolved, and the substance becomes brownish, just as when strong acid effluents from factories are discharged into ditches, or on to the black mud banks of neglected rivers, a liberation of sulphuretted hydrogen occurs. In the tank, however, the ferrous sulphide is protected by the ammonia; on reaching the oxidation stage it is converted into a basic ferric sulphate, forming an ochreous coating on the materials, which considerably assists in the transfer of oxygen.

4147. Do not the bacteria escape from the septic tank or any other anaërobic chamber?—Yes; but a large number remain entangled in a zoogloea mass either at the top or bottom of an unobstructed tank, or as a layer on the surface of the flints or other filling material.

4148. Is there any danger of pathogenic organisms escaping?—This important point was raised at the Exeter Local Government Board Inquiry, referring to the pathogenicity of the product after anaërobic treatment, since it has been suggested that, whilst cultivating the bacteria necessary for the destruction of the organic matter in sewage, the pathogenic organisms present in the crude sewage will not only survive but may possibly multiply, and so cause the effluent to be dangerous to health. It is important, however, to remember that the bacterial processes are not novel, but are identical with those which obtain in nature, so that effluents from sewage farms are strictly comparable with filtrates obtained after either a "coarse bed" or an anaërobic treatment. Mr. Groves, in his recent evidence before the Water Commission, hoped that the Local Government Board would not depart from their past position with regard to land treatment, as from the typhoid statistics for London, he argued that the present method of dealing with sewage was satisfactory. Although with any new scheme it is difficult to obtain direct evidence as to its ultimate effect upon a river water which is subsequently to be used as a drinking supply, one must recollect that under existing circumstances the removal of all kinds of bacteria from the river water is attempted by those who desire to use such water for drinking purposes, so that, even assuming that bacterial systems tend to increase the bacteria in the river, they do not make any new departure necessitating a reconsideration of our methods of water purification. Even if an anaërobic treatment alone resulted in an effluent which possessed toxic properties disastrous to a small river, it must be recollected that no process is at present suggested which does not involve a full and efficient aerating filtration as a final method of purification, and it is the pathogenicity of such filtrates upon which information is wanted. Satisfactory evidence on

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most of the systems is now available, from which, I think, we are justified in concluding that, even if towns on a river like the Thames adopted bacterial schemes, the pathogenicity of the London water supply would not be adversely affected. With intermittent fine bed filters following coarse bed or chemical treatment, as at Leeds and London, fish have lived in the filtrate. At Exeter Dr. Cartwright Wood examined the tank effluent, the filtrate, and the river water before and after admixture. Broth inoculated with these fluids and incubated for forty-eight hours had no effect upon rabbits or guinea pigs when 2 c.c. was injected subcutaneously. When inoculated for eleven days, the tank effluent and the water at Belle Isle contaminated with the untreated town sewage were found to be morbific, but the filtrate and the water at Salmon Pool Weir some little distance below the town contained so little morbific material of any kind that even with this severe test both animals remained alive and perfectly well. Dr. Woodhead in his report concludes "that none of the organisms themselves found in the tank effluent are capable, in the quantities present or in which they can grow even in broth, of setting up any morbid changes. With regard to typhoid fever, Lawes and Andrews some years ago showed that some liquefying organisms have a germicidal effect upon typhoid bacilli, so that their sojourn in a septic tank or their arrest in an anaërobic upward filter, with such organisms diminishes instead of increases their chances of survival. Dr. Pickard, of Exeter, has proved this fact again experimentally by introducing an emulsion of the typhoid bacilli into a septic tank, when he found that instead of increasing they rapidly diminished until after fourteen days less than 1 per cent. of the number introduced were surviving. The same investigation also proved that filtration was even more efficient in removing typhoid bacilli, as he found that filtration as conducted at Exeter removed about 90 per cent. of typhoid bacilli from sewage inoculated with this organism, and that subsequent filtration of tank effluent containing no typhoid through the same filter yielded filtrates containing only about 1 per cent. of the bacilli introduced in the first filtration, showing that the environment was unsuitable for their development if their absence from the first filtrate was due only to a straining action. Dr. Houston with the Ducat filter has shown that with sewage containing 1,200,000 B. coli per c.c. a filtrate is obtained which contained no colonies resembling this organism in this quantity; and that sewage containing between 1,000 to 10,000 spores of B. enteritidis sporogenes per c.c. contained after filtration less than 10 per c.c., whilst the aërobic bacteria causing liquefaction of gelatine were likewise reduced from 22 to less than 1 per unit. In my own work I have proved that the spores of B. enteritidis sporogenes survive, as might be expected, the septic tank treatment, but Houston has shown, as stated above, that 99 per cent. can be removed if the tank be followed by a well aerated filter. Before this evidence of the comparatively innocuous character of the filtrates from bacterial systems was available I pointed out that subsequent chemical treatment could be used for sterilising the filtrate if necessary. Such reagents as may be conveniently employed may be called "finishers," as when employed the resulting purified sewage is satisfactory both from the chemical and bacterial points of view. Chlorine is one of such reagents, and the late Dr. Kanthack has established the fact that with one grain to four gallons of the tank effluent or to five gallons of filtrate, with a period of contact of about five minutes, the number of bacteria can be reduced from any number (even millions) that may be present to 10 to 50 per cubic centimetre, and that no pathogenic organisms were found in any of the numerous samples of Maidenhead sewage finished in this way. I found at the same inquiry that on adding 1·77 parts of available chlorine per 100,000, although about half the amount immediately combines with any organic matter present, if the aerating filter has not worked efficiently the micro-organisms by contact with the remainder are gradually killed, so that plate cultivations of such sewage taken after fourteen minutes showed no growth with 3½ days incubation.

4149. Have you specially investigated the chemical changes in the purification of sewage in reference to the formation of nitrites and nitrates?—The changes in the natural purification of sewage lead more to the production of nitrites than of nitrates. In published analyses the former have not been sufficiently recognised. But nitrous acid and nitrites are well-known carriers of oxygen; they readily absorb oxygen from the atmosphere, or dissolved oxygen from a river water, and yield it again to the organic impurities, oxidising them to carbonic acid and water. From this useful instability, they count in many analyses in the "oxygen consumed," and, therefore, lead to a higher estimate of the organic matter. As an example of the production of nitrites, three Exeter filtrates, which on June 18th contained only "heavy traces," were analysed on June 30th, twelve days later.

PARTS PER 100,000.

Number.	Original N as Nitrate.	After 12 days.	Original N as Nitrite.	After 12 days.
VI.	1·01	1·152	Very heavy trace	0·48
VII.	0·590	0·624	Heavy trace -	0·666
VIII.	0·696	0·768	Heavy trace -	0·55

A later sample will further illustrate this instability:—

	Nitrogen as Nitrates.	Nitrogen as Nitrites.
Nov. 10th, 1897 -	1·49	·030
Nov. 18th „ -	1·51	·74
Dec. 2nd „ -	2·58	Trace.

In an effluent from the septic tank at Exeter, on November 10th, the nitrate was 0·030, the nitrite none; on December 2nd, the nitrate was 0·060, the nitrite excessive, so that the production of nitrite can proceed, in some cases, independently of the reduction of nitrate.

4150. Does this oxidation of carbon by the agency of nitrates and nitrites agree with the opinions of other observers?—So long ago as 1886, Gayon and Dupetit (Station Agronomique de Bordeaux, 1886) investigated the change of nitrates to nitrites with evolution of nitrogen oxides and nitrogen gas by the agency of bacteria. The disengagement of these gases is an important and till now unrecognised element in the purification, as they are without odour and innocuous. Two organisms were isolated from sewage, which in the presence of organic matter, decomposed nitrates with production of nitrogen and nitrous oxide. They state that in a nitrated medium they were anaërobic, taking oxygen from the nitrate, and that in certain solutions as much as 9 grammes per litre of nitrate could be decomposed. By exact analysis of the evolved gases, and of the fermented liquids, the authors show that the whole of the nitrogen of the nitrate is evolved as gas, and that the whole of the oxygen of the nitric acid is combined with the carbon of the organic matter to form CO_2, a portion of which may be evolved as gas, while the remainder combines with the base to form an acid carbonate. Organic matter is essential to the reaction. "1 grm. KNO_3 requires 0·148 C or 0·273 grm. of albuminoid matter for its complete decomposition." The $N + N_2O + CO_2$ account for all the nitrogen, carbon, and available oxygen of the nitrate. The denitrifying bacteria will not develop in liquids deprived of nitrate and out of contact with air, nor will they attack organic matter under these circumstances. The authors further proved denitrification to be a fermentation which consists in the direct burning up of organic carbon at the expense of the oxygen of a nitrate.*

4151. You have investigated the numerical relations between the various quantities?—Yes, in December, 1897, before the Society of Arts, I published the following table:—

* Recently confirmed by Ampola and Ulpiani, Gaz. Chim. Ital. 28 (1) 410: J.S.C.I., Dec. 1898, 1160.

Number.	Description	N as nitrate.	O in nitrate $N_2 : O_5$.	N as nitrite.	O in Nitrite $N_2 : O_3$.	Total available oxygen (lowest estimate).	Oxygen consumed in 4 hours.	Ratio of available O to O consumed.	Volumes of oxygen-saturated water required to yield all the O consumed.	Volumes of oxygen-saturated water required to supplement the available oxygen.	Albuminoid NH_3.	Per-centage of N oxidised.
1	Exeter septic tank filtrates average, Nov. 1896.	·496	1·42	heavy	–	1·88	0·91	2 : 1	1·10	0	0·50	12
2	Ditto, June 1897 - - - - -	·848	2·44	·565	·970	3·82	0·966	4 : 1	1·21	0	0·412	33
3	Weybridge raw sewage, June 12th, 1896.	0	0	0	0	0	4·00	0 : 1	5	5	1·05	0
4	Yeovil raw sewage, June 15th, 1896 -	0	0	0	0	0	5·87	0 : 1	7	7	1·135	0
5	Wembley sewage farm effluent, June 22nd 1896.	·75	2·14	heavy	–	2·14	1·79	1·2 : 1	2·1	0	0·90	48·7
6	Aylesbury sewage effluent, June 22nd, 1894.	·08	0·23	trace	–	0·23	7·23	·032 : 1	8·4	8	1·3	1·3
7	Croydon sewage farm effluent, April 26th, 1895.	·88	2·51	heavy	–	2·51	1·29	1·94 : 1	1·5	0	0·07	68
8	Precipitation and coke breeze filter, Dibdin, 1894.	·202	·577	–	–	·577	1·04	·55 : 1	1·34	·55	–	–
9	Ditto, 1895 - - - - - -	1·10	3·14	–	–	3·14	1·26	2·5 : 1	1·47	0	–	–
10	Pearmain & Moore's average : Exeter filtrate effluent, May and June, 1897.	1·3	3·71	none?	–	3·71	0·47	8 : 1	·55	0	0·16	43
11	Dibdin's average Exeter filtrates, April and June, 1897.	·504	1·44	·361	·483	1·87	0·55	3·4 : 1	·686	0	0·11	17
12	Exeter raw sewage - - - - -	0	0	0	0	0	6·56	0 : 1	8	8	1·40	0
13	Exeter septic tank effluent - - -	·041	·117	trace	–	·117	4·32	·027 : 1	5	4·9	0·64	1·9
14	Sutton crude sewage - - - - -	0	0	·021	·037	·037	6·5	·006 : 1	7·5	7·4	1·13	0·2
15	Sutton effluent - - - - - -	·587	1·68	·23	·28	2·17	2·39	·9 : 1	2·8	0·2	0·47	19
16	Sutton filtrate - - - - - -	1·58	4·37	0·067	·115	4·485	0·92	5 : 1	1·1	0	0·24	54
17	River Brent, Perivale Rectory, June 1896.	0	0	faint trace.	–	0	2·32	0 : 1	3	3	0·65	0

Therefore, after partial nitrification in a filter, this action of another class of bacteria, which absolutely require a certain amount of organic carbon as food, converts the latter into carbonic acid and harmless gases such as N and N_2O, the oxygen required being taken from the air or from that dissolved in the water. The change is illustrated in the above table of typical sewages and effluents, in which the "available oxygen" is that present as nitrate or nitrite, and the amount of carbonaceous matter requiring destruction is measured by the ordinary figure of "oxygen consumed" as determined by permanganate, since after four hours heating with permanganate no dangerous matter can be left. The table also shows that the available oxygen as nitrates and nitrites is in certain effluents quite sufficient in most cases to deal with the organic matter, even without help of the oxygen dissolved in river water. A large number of the published analyses of effluents are vitiated by the fact that the samples have not been analysed until some days after collection, frequently at the end of a long transit by rail or other conveyance, during which the agitation and inevitable contact with air will have considerably altered the composition in a favourable sense. It is, therefore, desirable, wherever possible, to analyse an effluent within a very brief time from its collection, and the more important determination should be made on the spot within a few minutes of the discharge. Although this is undoubtedly the only fair procedure, such analyses are not of course comparable with those carried out under the usual conditions which give an apparently higher quality to the effluent, but they demonstrate the existence of the rapid and beneficial improvement in some effluents which I consider, with Adeney, one of the main criteria of safety.

4152. Have you found that the purification does not always take the same course?—Yes; the results are the effect of the simultaneous action of different organisms, which action varies according to their numbers, activity, or the character of the original sewage, besides the conditions of light, air, and temperature.

4153. Have you found a reduction in the organic carbon, without a corresponding decrease in the amount of the total nitrogen, though the character of the nitrogen may be changed?—Yes; this is shown by my analyses of Caterham effluents at short intervals:—

Caterham.	No. 1.		No. 2.		No. 3.		No. 4.		No. 5.		Average.
	Jan. 26.	Feb. 1.	Jan. 27.	Feb. 1.	Jan. 28.	Feb. 1.	Jan. 30.	Feb. 1.	Jan. 31.	Feb. 1.	First day.
Ammoniacal N - -	12·15	11·9	12·56	12·1	12·35	11·54	21·4	20·6	23·8	—	18·45
Organic N - - - -	·618	·412	·823	1·03	·618	·41	1·23	1·44	0·82	—	·822
Nitrous N - - - -	·148	·074	1·924	1·702	1·184	1·40	0·407	0·407	0·592	0·666	·840
Nitric N - - - -	7·68	9·0	4·14	4·36	5·60	6·46	10·3	10·64	6·46	5·52	6·84
Total Nitrogen - -	20·596	21·386	19·447	19·192	19·752	19·81	33·337	33·087	31·672	—	25
Oxidized Nitrogen - -	7·828	9·74	6·064	6·062	6·784	7·86	10·707	11·047	7·052	—	7·68
Percentage of Nitrification	38	45·5	31	32	34·5	39·6	32·	33·4	22·3	19·5	30·7
Oxygen consumed - -	3·32	2·24	6·27	4·43	4·19	3·47	4·85	2·78	4·52	—	4·63
Chlorine - - - -	18·5	—	19·75	—	21·5	—	22·15	—	24·35		
Percentage of reduction in the Oxygen consumed	—	32·5	—	30	—	17	—	43	—		

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The samples were kept in bottles partially full. The chief change seems to have been a transfer of the oxygen of the air by means of the nitrous to the carbonaceous matter. The nitrifying and nitrosifying changes appear to have gone on continuously, the nitric being reduced to nitrous by the carbonaceous matter, which was thereby oxidised, and the nitrous again absorbing oxygen and reforming nitric. In Nos. 1 and 3 the nitrogenous organic matter has taken part; but the change as a rule is not a Gayon and Dupetit one, as no loss of total N as gas has occurred. It is simply an oxidation of carbon.

4154. With a weaker sewage may the nitrification be exceedingly rapid?—Yes, as the following results obtained at Ashtead in 1898 with Mr. Scott Moncrieff's process will show:—

PARTS PER 100,000.

	I.		II.		III.	
	0	9	0	9	0	9
Chlorine	9·0	7·5	6·3	6·4	5·5	5·5
Ammonia	11·5	0·25	4·25	0·755	4·0	0·42
Albuminoid Ammonia	1·5	0·60	2·98	0·475	1·472	0·107
Nitric Nitrogen	0·12	9·0	none	5·98	none	4·34
Nitrous Nitrogen	none	slight trace	none	0·06	none	0·084
Total unoxidized N.	12·35	0·60	6·60	1·12	5·35	0·148
Organic N.	2·06	0·394	3·10	0·50	2·06	0·113
Total Nitrogen	12·47	9·60	6·60	7·16	5·35	4·522
Oxygen consumed	9·84	0·589	9·05	0·608	7·52	0·632

PERCENTAGE PURIFICATION.

	I.	II.	III.
(1) Oxygen consumed	94	93·3	91·6
	Average 93.		
(2) Oxidation of Nitrogen	93·7	84·3	96·7
	Average 91·6.		

Here again the total amount of nitrogen is not greatly reduced. The time occupied in passing through the nine trays is about eight minutes. It will be noticed that the purification is very constant under varying conditions, and that a very close agreement exists between the amount of purification, measured by carbon oxidation and by nitro oxidation. The columns marked "0" show the composition of the unoxidised sewage, after the hydrolytic changes resulting in the solution of the suspended organic matter have been effected. The columns marked "9" show the final filtrate, as it issues from the lower bacterial tray. It will be further noticed that while the percentage of purification is very high, judged from any standard, the point of greatest interest is the ratio of the oxidised to the unoxidised constituents, and it will be generally admitted that an average production of 6·44 parts per 100,000 of nitric nitrogen by a purely natural process throws a new light on the capacities of the system as a whole, and places the effluent above suspicion wherever it may be discharged. The nitrification in the effluent from the last tray still continues, as is shown in the previous table (Q. 4,153).

The accompanying curves show the progress of the change of nitrogen in the different trays:— Appendix No. 19 (B and C).

TABLE of COMPARATIVE NITRATION.—Parts per 100,000.

	Garfield: Manufacturing.		Garfield: Domestic.		Dibdin-Sutton.		Cameron: Exeter.		Scott-Moncrieff. I.		II.		III.	
Chlorine	22·4	10	11·0	10	12·8	10	7	10	7·5	10	6·4	10	5·5	10
N as Nitrite					·067	·052	trace	trace	trace	trace	·06	·09	·034	·062
N as Nitrate					1·53	1·20	1·06	1·51	9·0	12·0	5·98	9·35	4·34	7·9
Oxidized N	1·67	0·75	0·95	0·86	2·20	1·25	1·06	1·51	9·0	12·0	6·04	9·44	4·37	7·96

4155. Will you kindly give us your views as to the significance of the production of nitrites?—I have already mentioned that the changes in the natural purification of sewage lead more to the production of nitrites than of nitrates. For the group of transformations working to this end, I use the term "nitrosification," implying the production of nitrites *by partial oxidation*, as distinguished from the special reduction of nitrates called "denitrification," which was proved by Gayon and Dupetit to be "a fermentation involving direct burning up of the organic carbon at the expense of the oxygen of a nitrate." Nitrosification is not nearly so delicate a process or so difficult to initiate or control as nitrification, which it seems to invariably precede. It occurs best in the presence of diffused light and of a moderate amount of air, and is quite consistent with the growth of large numbers of green or brown algæ which are at the same time engaged in reducing any nitrates present. The following experiments show some of the conditions of the changes:—

Experiment 1.—Nine volumes of a tank effluent free from nitrate or nitrite were mixed with 1 volume of a coke breeze filtrate containing 4·34 parts per 100,000 of nitric nitrogen (no nitrite), sealed in a flask without air, and kept for five days in a dark chamber at 150° C. By this time the whole of the nitric nitrogen, amounting to 0·434 parts in the mixture, had disappeared, without formation of either nitrite or free nitrogen. The same liquid afterwards in a vessel partially full and exposed to light yielded nitrites in abundance.

Experiment 2.—A strongly urinous effluent to which potassium nitrate had been added in the proportion of 10 parts per 100,000 was seeded with the organisms (collected by a Pasteur filter) from a coke-breeze filter, and kept in the dark at room temperature in bottles nearly full. After fourteen days the liquid was turbid and had a sweetish urinous odour: a partial vacuum had been produced, as air entered freely on easing the stopper. The composition before and after was in parts per 100,000:—

—	Nitric N.	Nitrous N.	Free NH_3.	Org. N.	Loss of N in other Forms.	Physical Characters.
At commencement	10	–	8·0	2·89	–	Yellow, turbid.
After 14 days	7·06	1·77	7·5	2·38	1·17	As above, odourless.

In one day the formation of nitrite from nitrate in the dark was found to be equal to 0·21 parts of nitrous N. per 100,000.

Experiment 3.—A urinous effluent similar to the above preserved in a closed bottle containing air in diffused daylight. Analyses:—

—	Cl.	Nitric N.	Nitrous N.	Free NH_3.	Org. N.	Loss of N.	Physical Characters.
Original	23.5	None.	Trace.	35·0	6·17	–	Yellow-brown, turbid, odour very foul, urinous.
After 67 days.	23·5	Trace.	1·87	34·5	3·30	1·0	Much less colour, deep brown flaky sediment, slight musty odour.

At first a white bacterial scum had formed, but had sunk with the sediment. No algæ were visible.

Experiment 4.—The result of the last experiment was diluted with four times its volume of tap-water, containing 7 cc. of free oxygen per litre and 0·2 parts per 100,000 of nitric nitrogen, and preserved in the light in a half-full bottle. In five days it was clear, inodorous, and nearly colourless, and had only a very slight deposit in which green algæ had made their appearance. But the nitrosifying change was still prominent; the nitrous N had increased to 3·375 parts, calculated on the original, while the nitric N in the mixture was ·091, so that nitrate had actually been reduced. After this the nitrifying organism seems to have become predominant, as in fourteen days the liquid contained 3·06 parts per 100,000 of nitrogen as nitrate, and only traces of nitrite and of free ammonia, the green alga (apparently protococcus viridis) being luxuriant, and the water clear, nearly colourless, and almost devoid of dissolved organic matter.

These experiments explain the causes of failure noticed when attempts have been made to deal with raw sewage by bacterial action without due provision for allowing the changes to take place in natural sequence.

4156. Have you found a loss of free ammonia without a corresponding production of nitrates?—Yes. With a liquid containing 10 parts per 100,000 of nitrogen as ammonia and 10 parts of chlorine, which was seeded with garden soil in an actively nitrifying condition (containing 0·1 per cent. of nitric nitrogen), and passed through coarse filters of gravel and coke breeze, I obtained the following results. The nitrite at the time was only approximately determined:—

Material.	Date.	Ammoniacal N.	Nitric N.	Nitrous N.	Ammoniacal + Nitric N.	Loss of N (excluding Nitrite).
Gravel	Oct. 22	5·08	1·28	Distinct	6·36	3·64
	„ 27	6·18	0·102	Very heavy	6·28	3·72
	Nov. 11	3·17	0·052		3·22	6·78
Coke	Oct. 22	8·23	1·66	Trace	9·89	0·11
	„ 27	7·40	0·38	High	7·78	2·22
	Nov. 11	4·10	0·04	Excessive	4·14	5 86

Showing that (1) in each case there was a heavy loss of nitrogen as gas, even allowing for the increase in nitrite, which does not amount to 0·1 or 0·2 per 100,000. (2) This loss is accompanied by reduction of nitrate, *i.e.*, denitrification, accompanied by the production of nitrite. (3) Other experiments show that the nitrite acts as a carrier of oxygen from the air to the carbonaceous matters.

4157. Have you conducted any experiments on the influence of algæ in the purification?—Yes. On February 9th, 1898, an effluent contained:—

Ammoniacal N.	Organic N.	Total unoxidised N.	Nitric N.	Nitrous N.	Total oxidised N.	Total N.	Cl.	Oxygen consumed.
1·87	0·44	1·81	5·47	·105	5·575	7·38	6·2	·838

On March 3rd (22days) the nitric nitrogen was 7·68 (which is more than the total N of the previous, therefore N must have been taken up from the air). [The sample was kept in a bottle half full, exposed to diffused light; the air was renewed occasionally. The sediment was originally very slight; after a time it increased, and became brown; then a strong green sediment formed.] On March 10th (29 days) it was again examined: Nitric nitrogen, 3·21; nitrous N, trace; ammonia, trace. The air in the bottle contained the ordinary amount of oxygen. The water was bright, but had a faint earthy odour and a slight greenish tint. The greenish-brown sediment showed under the microscope "brownish flocculi with mineral matter, a few rotifers, spicules of a fresh-water sponge, streptococci and micrococci not numerous, a few infusoria, green algæ abundant." The total unoxidised N was 0·04 parts, whereas the oxygen consumed was 0·832, or about the same as the original. Shows that the algæ have used up nearly all the unoxidised nitrogen, and the greater part of the oxidised, but have not touched the carbonaceous matter.

Experiment on Induction of Nitrification.

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An effluent containing 1·59 parts of nitric nitrogen was placed in a sterile Petri dish on March 16th, 1898, and seeded with a small quantity of the sediment from another effluent in an active state of nitrification. At the same time a blank was mounted of the same water. Both were kept in the light at 60° F. On March 22nd (6 days) the blank was clear, the other showed some turbidity, owing to bacterial growth. Made up to the original volume with sterile water, and examined for nitrates, the two showed in nitric nitrogen:—

Blank, 1·51 parts, or practically unchanged.

Seeded, 2·34 parts, or an increase of more than one half.

The seeded sample contained a trace of nitrite and a small quantity of free ammonia. Under the microscope it contained algæ and a large number of infusoria in active motion. Showing that nitrification can continue in the presence of algæ when the nitrifying organisms are present, with a corresponding destruction of the free ammonia.

4158. Have you made experiments as to the effect of light and air on these changes?—Yes. I made an experiment by mixing the septic effluent with some of the liquid from the seventh of Scott-Moncrieff's nitrifying trays. When mixed in the proportion of 2 per cent. of the latter, it induced nitrification in the dark at ordinary temperatures when exposed to air. [0″ = original. 9″ = last tray.]

0″ was of a greyish colour and somewhat turbid.

9″ was nearly clear, no odour, and very little colour.

An incubation experiment with the last tray exposed to the light showed the dissolved oxygen to be:—

	Pts. per 100,000 by weight.
Feb. 25th, 2·38 cubic centimetres of O per litre =	0.34
Feb. 28th, 1·78 „ „ „ „ =	0·25

the second, having been exposed during the time in a closed full bottle to the light. Kept longer in a bottle half-full of air the nitrate was: On March 9th, 5·80; on March 23rd, 6·17 parts per 100 000, while the nitrite on the latter date was very heavy. Showing that the presence of a full supply of air is necessary.

Influence of Darkness and Light.

540 cc.'s of 0″ and 60 cc.'s of 9″ were mixed and kept freely exposed to air, half in the dark, and half in diffused light. The nitrite and total unoxidised N were determined at various times (the volume being made up to original bulk).

—	Original.	1 day.		3 days.		5 days.	
		Light.	Dark.	Light.	Dark.	Light.	Dark.
Unoxidised nitrogen	5·26	3·88	3·70	1·54	2·47	1·03	1·54
Nitrous N	trace	–	–	–	–	·360	·150

Showing that the presence of diffused light is advantageous to the nitrous change.

4159. How is it possible to form an estimate of the loss of nitrogen as gas?—Besides the formation of free ammonia in the transition or preparatory stage, and the conversion into nitrite and nitrate at a later period, there is a considerable dispersion of organic nitrogen in the form of innocuous gases. I believe I am the first to propose an expression for the measurement of this important phase of the purification, obtaining the data from the

Ratio of the Chlorine to the Total Nitrogen.

In perfectly fresh excreta, taking the solids and liquids together, the total nitrogen somewhat exceeds the chlorine. This proportion will remain unchanged when diluted with water containing only the ordinary small amount of chlorine, as long as the nitrogen remains in fixed forms. Therefore the ratio is applicable to fresh sewages generally, independent of dilution, but will be immediately altered by the production of gas. Let Cl and N be the

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parts of chlorine and nitrogen respectively, the "residual ratio" will be:—

$$R = \frac{N \times 100}{Cl}$$

or in cases of great dilution, with a high chlorine W, in the water supply:—

$$R = \frac{N \times 100}{Cl - W}$$

The simpler formula is usually sufficient. In the original excreta the number R will be somewhat over 100, in fairly fresh sewage it will be about 100; in bacterial effluents, on the other hand, the fall of R will indicate the gaseous dispersal of nitrogen. With chemical or mechanical treatment R will fall, owing to the abstraction of matter as sludge. Where heavy nitrification has been the main feature, there may be little or no fall, this afterwards occurring rapidly in the process of denitrification, when the effluent is admixed with other water.

The following table bears on this point:—

TABLE of the relation of Nitrogen to Chlorine, and of Oxidation.

	Chlorine.	Total Nitrogen.	R. $\left(\frac{N \times 100}{Cl}\right)$	Percentage of Oxidation.
Raw Sewages:—				
Exeter	7·5	6·87	86	Trace.
Sutton	8·99	8·81	98	0·2
London	10·4	7·06	68	Trace.
Effluents and Filtrates:—				
London Outfall (removal of the N by precipitation)	10·5	4·26	41	Trace.
Exeter Septic Tank	7·5	5·96	80	·2
Exeter Coke Breeze Filtrate	7·5	3·42	46	32
Sutton Bacterial Tank	6·94	2·97	43	19
Sutton Coke Breeze Filtrate	6·84	2·00	30	56
Ashtead Tank Effluent 1	6·3	6·60	105	0
Ashtead Filtrate	6·4	7·16	112	84·3
Ashtead Tank Effluent 2	5·5	5·35	97	0
Ashtead Filtrate	5·5	4·52	82	96·7

4160. What is your opinion as to the standards of purity that have been proposed for sewage effluents?—As nitrogen is significant of the more dangerous forms of pollution, a calculation of the ratio between the different forms of nitrogen furnishes more useful information than a mere consideration of its amount, inasmuch as nitrogen compounds when oxidised are harmless, but when unoxidised are liable to occasion smells, and to be in other respects deleterious. A certain quantity of nitrogen is lost as gas during the changes, but the residue will give a minimum measurement of the original sewage strength. The proportion between the oxidised and unoxidised nitrogen will then denote the extent to which the sample has been purified. A judgment can therefore be formed from the sample without an analysis of the original sewage, as the chlorine contents also give a clue to the strength, and thus such a method would have an advantage over the ordinary system of calculating sewage purification, as it obviates the difficulty of obtaining conformable samples. Even where, as I have elsewhere insisted should be done, a correction is made to a standard chlorine value in comparing the sewage entering and the effluent leaving a certain works, the system I suggest will still have great advantages. As ammonia must be recognised as a preparatory or transition, and not a finished product, it must be considered as part of the residual unoxidised sewage, and only indicates progress towards complete purification, and gives a criterion as to whether a process is working satisfactorily. A large number of the failures in sewage disposal methods have been owing to the effort to obtain by chemical treatment or filtration a liquid from sewage which should bear some resemblance to drinking water; such an end is impossible without impracticable expenditure, time, and space, attended by disastrous breakdowns at intervals. Fortunately methods have been found which by natural agencies allow us to carry the purification to a rational and harmless stage, when such factors as time, light, volume of oxygen, and various life of a river will be more than sufficient to deal with the effluent. A few examples to show how the percentage of oxidation reveals the purification effected by different agencies may be quoted here:—

	Oxygen Consumed.	Parts per 100,000 of Nitrogen.				Percentage of Oxidation.
		As NH_3.	Organic.	Total Unoxidised.	As Nitrite and Nitrate.	
A raw sewage	6·66	3·0	6·12	9·12	none	none
A filtrate effluent	0·78	2·4	0·92	3·32	1·16	26·0
Another ditto	0·36	0·92	0·44	1·36	1·09	44·5
London river water	0·20	0·0016	0·049	0·051	0·305	86·0
Same filtered	0·176	none	0·026	0·026	0·254	91·0
Deep well in chalk	0·013	none	0·008	0·011	0·450	97·6

Furthermore, one has to consider not only the chemical but also the pathogenic qualities, and these are ignored by all existing standards. It is obvious that a very small amount of nitrogen or carbon, if in the form of ptomaines, would be sufficient to condemn an effluent. I have noticed that many dilute putrid sewages of offensive character have shown less albuminoid or organic nitrogen than the condemnatory limits of existing standards, so that these arbitrary rules are of little or no value. On the other hand, when a sewage has been subjected to nitrification, although the albuminoid ammonia may be higher than the old standards, the presence of nitrate seems to have a beneficial influence upon the quality of such sewage, and under these circumstances a greater quantity of albuminoid or organic nitrogen may be tolerated. The multitude of bacteria in sewage is so enormous, and their character so various, that a mere counting of their numbers must be unmeaning and inaccurate. The ratios, however, between either those liquefying and not liquefying gelatin, or between the aërobic and non-aërobic, or between those growing at ordinary temperatures and at blood heat, give much more valuable information. Whilst therefore any absolute number as a standard is undesirable, only a low number of organisms of the Coli group should be permissible in an effluent, with an absence of dangerous pathogenic forms. Absolute sterility in an effluent is at present out of the question, nor in general would it be necessary or even advisable, inasmuch as subsequent organic improvement would be prevented, but the destruction of pathogenic forms could be completed by a "finisher" like chlorine when special danger was present. Dr. Dupré some years ago introduced a method of ascertaining the condition of healthiness or otherwise of an effluent by enclosing it in a bottle and determining the free oxygen present before and after keeping. This seems a natural way of carrying out the "oxygen consumed" test. He observes (*Analyst*, August, 1898):—"Pure water remained aerated when bottled up, but water containing sewage de-aerated itself. An effluent that did not appreciably de-aerate itself might be admitted anywhere without fear of putrefaction." Unfortunately, although the actual work of this test can be carried out in a few minutes, the sample had to be allowed to stand for five to ten days. On similar—but less natural—lines, the "Incubator Test," adopted in the Manchester report on systems of sewage purification, maintains an effluent by itself at a warm temperature (five days at 80° F.), and determines the oxygen absorbed in three minutes before and afterwards, at the same time noticing any change of odour. The result is, however, again arbitrary, as an effluent is not intended to be stored by itself, but when finished, to be discharged at once into water which is moving and aerated. The results seem to be more favourable to effluents which have been sterilised by a chemical or precipitation process, but which have notoriously in many cases given rise to a subsequent nuisance, than to those containing the materials, bacterial and chemical, for rapid self-purification in a river. Mr. Dibdin has recently put forward this test, which he describes as follows:—"He had long since adopted in his own mind a physiological standard, viz., that the quality of an effluent should be such that fish could live healthily in it, ... such a definition involves necessarily the absence of poisons and the presence of oxygen." But while an effluent which kills fish is obviously unhealthy, it does not follow that one

where fish will live is therefore a good one. It is well known that fresh-water fish are gross feeders, and fish in large numbers are often seen to congregate at the mouths of sewers where fæcal matter is visibly floating, being attracted by the fragments of food and insects carried down by the sewage. Fish, in fact, are more affected by muddy water and by chemicals from factories than by excreta. Amongst the standards which have been proposed in the past, or have been adopted by local bodies, are the following, some of which have been repeatedly quoted in papers on the subject, while others are gathered tentatively from published documents, or from a consideration of decisions in disputed cases. None of them, however, have strictly the force of law; in fact, some have actually been disclaimed by the bodies to which they were attributed. The proportions are parts per 100,000:—Rivers Pollution Commissioners—Organic carbon, 2·0; organic nitrogen, 0·3. Thames Conservancy—Organic carbon, 3·0; organic nitrogen, 1·1. The Thames Conservancy state that they require a higher standard for effluents just above the intakes of the water companies than for those below. Derbyshire County Council—Albuminoid ammonia, 0·1; oxygen absorbed, 1·0. Ribble Board—Albuminoid, 0·1; oxygen absorbed, 2·0. Mersey and Irwell—Albuminoid, 0·14; oxygen absorbed, 1·40. Provisos as to amount of suspended solids, acidity, alkalinity, metals, etc., are inserted in some, and have special reference to manufacturing effluents. But in all these arbitrary limits, no account is taken of the volume of the river into which the effluents are discharged, although attention was long ago drawn to the purifying action of river water. The London County Council have recognised the fact that an oxidising agent added to the effluent at the time of contact with the river prevents any foulness. Provided, therefore, a river is well aerated, or an effluent is well nitrated, or an oxidising agent is supplied in sufficient quantity at the time of contact, an effluent may contain a larger quantity of organic matter than has been sanctioned in the past, and variations in such quantities are permissible under conditions varied in the above way. In America, from the work of the Massachusetts State Board of Health, Rudolph Hering fixes a limit to the amount of free ammonia permissible in a stream, and finds that if the flow of the stream is less than 2½ cubic feet per second per 1,000 persons (or one gallon per minute per person) "an offence is almost sure to arise"; but when the flow is greater than 7 cubic feet per second per 1,000 persons, then safety is assured. "In other words, when the free ammonia is greater than 0·12 part per 100,000 the conditions are probably objectionable." I find that these limits correspond to about 50 volumes of river water to average sewage in this country, and it is obvious that such conditions are only possible under very special circumstances, and the limit is much greater than we have found necessary in England. In other words, I agree with this author that *the quality of the stream*, and not of the effluent, should be taken as a basis, and that some fixed distance below the outfall in mid-stream should be specified as the locality at which samples should be taken.

4161. Have you any suggestion to make as to a practical standard?—Some time ago, in conversation with Mr. Henry Law, we arranged the following formulæ for the conditions of discharge into a stream. The basis I prefer to take is the same as that preferably adopted for waters, viz., 100 litres or 100,000 parts:—

Let X be the flow of the stream in 100 litres per minute.

O = grammes of free oxygen in 100 litres.

S = number of hectolitres of effluent discharged per minute.

M = grammes of oxygen required to consume the organic matter in 100 litres of effluent, as determined by the permanganate test after deducting that required by nitrites.

N = grammes of available oxygen as nitrate and nitrite per 100 litres.

This latter factor requires explanation. Warington, Munro, Gayon, and Dupetit, Adeney, and others, have shown that, always with the help of bacteria, the oxygen of nitrates and nitrites is available for the burning up of organic matter. In my own experiments I have found that the large loss of organic nitrogen noticed so frequently in analyses of sewage in progressive stages of change was not accounted for by the production of nitrous acid, of ammonia, or of nitrogen gas. Gayon and others have observed the formation of nitrous oxide, which, from its solubility and vague reactions, would ordinarily escape observation. Therefore, to be on the safe side, I have allowed for the available oxygen 2 atoms of O for every HNO_3, *i.e.*, N_2O_5 to N_2O_3, and 1 atom for HNO_2, or N_2O_3 to N_2O. The quantity of free oxygen in the stream will then be XO, and that required by the effluent will be S(M — N). Putting C as the ratio between the amount of oxygen in the stream and that which is required to oxidise the organic matter in the effluent—

$$XO = C(M - N)S.$$

Where there are no nitrates in the fluid—

$$XO = CMS.$$

If N be less than M, M — N = the deficit of oxygen in the effluent, requiring to be supplemented by the free oxygen in the river, such an effluent will throw a burden on the river, and cannot be considered in a satisfactory state; and it will be a question of volume and other circumstances whether it can be permitted to be discharged at all. Where XO is greater than (M — N)S there will be a chance of the stream dealing with the inflowing liquid; where the reverse is the case the addition must necessarily cause foulness. In favourable cases, where bacteria and algæ are active, and the oxygen of the river is able by their help to deal rapidly with the incoming residues, the minimum ratio between the volume of the stream and the volume of effluent that could be allowed to be discharged into it would be indicated by the value of C in the above equation, which would also approximately denote how far the population might increase before the proportion would be seriously disturbed. The minimum figure will be reduced by the nitrites or nitrates of the river water itself, and by the free oxygen which may be present in the effluent. River water may have 90 per cent. of its nitrogen oxidised, and, when saturated, contains about 700 c.c., or, approximately, 1 grm. of free oxygen per 100 litres. We may assume that with the almost unlimited exposure and admixture in a flowing stream, the requisite natural organisms are certain to be present. Hence, in theory, comparatively few volumes of a river water are necessary for supplying the oxygen requisite for even a raw sewage after its solids have been removed by filtration or subsidence. From this cause it is a common observation that the dissolved impurity remaining in a stream is a mere fraction of that in the volumes of sewage that have entered it in its upper course. But from the factor of time, and the inadvisability of denuding the river of its oxygen, which might be only gradually renewed from the air, it is necessary with the raw liquids of sewage to allow a considerably larger proportion of river water than the minimum above calculated. Dupré states that admixture with about 30 volumes of fully aerated river water prevents sewage from becoming foul, and ultimately purifies it. I have found the same result from a less quantity. Where the organic matter is well fermented, and the liquid advanced in nitrification, as in properly managed septic effluents, the case is far more favourable. Here, in the above equation, N is greater than M, and there is a surplus of available oxygen in the effluent—that is to say, an effluent of this kind not only does not absolutely require any dilution with river water, as containing within itself the elements of its own purification, but by its surplus oxygen is capable of actually improving the river into which it enters. This apparently paradoxical result in cases of polluted streams is paralleled by the effect of the addition of artificial oxidising agents, such as that of manganate of soda to the Thames at Crossness. In healthy effluents the quantity of available oxygen, N, in the above equation, is far higher than could be supplied by any process of mere aeration. As an example of the application of the formula XO = C(M — N)S, we may cite two rivers, the Thames and the Exe:—

	X.	O.	M.	N.	S.	C.
Thames - -	1100	0·4	4·3	0·23	100	1·08
Exe - - -	47	1·0	6·66	0·16	1·084	6·7

X and S are stated in million gallons.

The formula shows that the Thames with C = 1·08 has so narrow a margin of effective natural oxidation that it has often had to be supplemented, especially in warm weather, by the addition of chemicals. In the Exe, on the other hand, with C = 6·7, there is a large margin for natural purification. But we cannot, as a rule, throw the burden of the final changes on the stream on account of the time taken and the odours and deposit that generally ensue. On the other hand, an effluent that is in an active state of wholesome bacterial change, under the above conditions of free and potential oxygen, will conform to Adeney's proposed test:—"The limit of impurity to be

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allowed in a water should be such that when a given volume of it is mixed with a given volume of fully aerated river water, and the mixture kept out of contact with air, a decided oxidation of the ammonia originally present into nitrous or nitric acid shall be indicated." . . . . It will be noticed that this test is practically that suggested by Dupré many years ago. Such an effluent, as experience teaches, if clear and nearly free from odour, may be safely discharged into any river of moderate volume.

4162. What is your opinion about processes of analysis?

PROCESSES OF ANALYSES.

Free and Albuminoid Ammonia.

In every case ascertain approximately the quantity of ammonia by diluting a portion of the original and testing with Nessler, so as to find the amount that will be suitable to be taken for analysis.

1.—*The Original Wanklyn Process.*

100 c.c., or less, diluted with *pure* water to 500 c.c., and distilled with ignited $Na_2 CO_3$. Successive portions of 50 c.c. Nesslerized till NH_3 ceases to come over. This is put down as *free ammonia*, the "albuminoid" being then continued with permanganate as usual.

Objections.—(1) Ammonia does not cease to come over at any definite point, the alkali and heat gradually decomposing several compounds in the sewage. Consequently the "free ammonia" by this method is too high, and the "albuminoid" too low.

(2) The "albuminoid" is also too low, because the decomposition is never complete, hence, as is well known, it only represents a somewhat uncertain fraction of the nitrogenous matters. This objection applies to any of the modifications of the Wanklyn process. Several chemists have found that if, after the completion of the ordinary process, more "pure water" be added, and the distillation continued, a further quantity of ammonia will be obtained.

(3) It is very difficult to obtain "pure water" for dilution which will not give some ammonia when distilled with alkaline permanganate. Hence, it is customary to subtract an amount for a "blank" experiment. The principle is, however, a bad one, and may introduce great error, as the "blank" is not constant. It will be remembered that a similar correction is applied to the results of Frankland's combustion process, and I have pointed out that in many cases the "blank" may actually be over the amount obtained. This objection always applies to the ordinary Wanklyn process, where dilution before distillation is practised.

The majority of analysts employ the original Wanklyn with preliminary dilution, hence the published results almost invariably show too much free, and too little albuminoid, ammonia.

(4) The volatile bases produced in the fermentations are, in the ordinary method of analysis, put down as "free ammonia," which includes not only the ammonia really existing in the free state, but also that combined with the organic acids as salts, as well as such compound ammonias as react with Nessler test. Many years ago Young pointed out that in the usual mode of distillation a good deal of volatile nitrogenous matter escaped which was not recorded by Nessler. I have often also indicated that the conventional procedure in the Wanklyn determination gives an "albuminoid ammonia" far short of the fixed organic nitrogenous matter, which probably accounts for such low figures as 0·34 (with 13·8 of chlorine), 0·24 (with 10·3 of chlorine), etc., for raw sewages in the recent Manchester and other reports. The Kjeldahl process, on the other hand, gives nearly the whole of the ammoniacal and organic nitrogen.

Process by Difference. Total minus Free.

Generally adopted in America, and by some in England. One quantity of pure water, plus a little $Na_2 CO_3$, is distilled till the distillate is ammonia-free, then the sewage is added through a tap-funnel, and the distillation continued for free ammonia.

Another quantity of pure water is distilled with alkaline permanganate till ammonia free, the sewage added, and distilled for total ammonia—the difference gives albuminoid. This is an improvement, as it avoids objections 3 and 4, but is still open to objection 1.

A modification I have used is as follows:—

1. 10 c.c. of the sewage is placed with 500 c.c. of a good tap water, 50 c.c. of alkaline permanganate, and some ignited pumice, in a round-bottomed Jena flask, slanting upwards and connected by a wide tube of black rubber with the expanded, curved-over top of a vertical worm arranged with others in a tank of running water. 250 or 300 c.c. is distilled over, and a fraction Nesslerized. 500 c.c. of the tap water is separately distilled, carefully Nesslerized, and the amount of ammonia deducted, giving the *total ammonia*.

2. 1 c.c. of the original is diluted to 50 c.c. or more with ammonia-free water, and directly Nesslerized. I find that with this dilution the titration can be accomplished without interference from turbidity, but the precipitation of the lime as oxalate can, of course, be adopted. This method is the only one that gives the amount of ammonia and its salts actually existing ready-formed in the liquid. It also gives the maximum amount of albuminoid, which reaches to two-thirds or more of the organic N as found by Kjeldahling.

In Nesslerizing the standard practice is 50 c.c. of liquid, 2 c.c. of the reagent, and a five minutes' reading.

OXYGEN CONSUMED.

Dibdin takes 70 c.c. of the sample.
10 c.c. of sulphuric acid (10 per cent. by volume).
10 c.c. of permanganate (1 c.c. = 1 milligrm. O).

Four hours at 80° *Fahrenheit.*

"In some cases of strong sewage, take only 7 c.c. and make up to 70 c.c. with 'permanganated water.'"

"In manufacturing refuse it is advisable to ascertain the O absorbed *at once*, and deduct from the 4 hours."

Mersey and Irwell Board.
70 c.c. effluent, 50 c.c. permanganate (1 c.c. = $\frac{1}{10}$ mgm. O).
3 minutes, and 4 hours, at "about" 60° Fahrenheit.

For the 3 minutes add permanganate from a burette to "70 c.c. effluent + 10 cc. H_2SO_4 (one in four) the colour of the permanganate forming a sufficiently delicate indicator."

Carter Bell.
20 c.c. effluent, 50 c.c. distilled water, 10 c.c. H_2SO_4.
10 c.c. permanganate, ordinary temperature, 4 hours.

For the short time, add 10 c.c. permanganate at once, allow to act 3 minutes, then titrate with KI and thio.

Rideal.
Exeter filtrates: (80° F. used *by request*).
50 c.c. + 25 c.c. permanganate (1 c.c. = ·0001 grm. O), made up to 250 c.c. with pure water + 6 c.c. pure concentrated H_2SO_4, 4 hours 80° F.
Sewages: 10 c.c. — the rest as above.
In laboratory, effluents are done thus: 50 c.c. + 50 c.c. permanganate and 50 c.c. sulphuric (one in four), 2½ hours at 80° *centigrade.* [*Always made up to same volume, 250 c.c.*]

Kjeldahl.—The modifications are very numerous.

I heat 10 c.c. of sewage with 10 c.c. of pure $H_2 SO_4$ till colourless, and reduced in volume to about 5 c.c. I do not find any need for the addition of $K_2 SO_4$, since alkalies are present, nor of Hg. By certain experiments I have proved that the nitrates and nitrites even in highly nitrified effluents, do not cause any material loss of organic N, when the above excess of $H_2 SO_4$ is used.

The liquid obtained is washed into a 100 c.c. measure, diluted to about 50 c.c., a calculated excess of pure 50 per cent. soda added, cooled, made up to 100 c.c., and allowed to stand till the precipitate deposits. A suitable fraction of the clear liquid is then diluted with pure water to 50 c.c., and Nesslerized. I usually do this simultaneously with the free and albuminoid ammonias, as the large number of samples that it has been necessary to daily analyse with rapidity on account of the quick changes that sewage undergoes, have compelled a simplification of methods.

The ordinary process of distillation and titration with alkali might attain more accurate results, but would involve the treatment of large quantities (½ to 2 litres), a great expenditure of time, and a volume of sample that is not often attainable.

BACTERIOLOGICAL EXAMINATION.

Counting plates, temperature, and time.

Dr. Frank Clowes, and Dr. Houston. } London County Council.

Abstract.

Sterile bottles completely filled with the sewage: cultivations in every case on same day, and as soon after collection as possible.

Dilute with sterile water: the two most convenient dilutions are 1 in 10 and 1 in 10,000.

For the *number*, gelatine plates should be used. If suitably diluted, and continually observed, properly grown colonies can be obtained even when rapidly liquefying species are present. When agar is used the numbers are too low, and the differentiation is more difficult.

From 0·1 to 1·0 c.c. of crude sewage diluted with 10,000 volumes of sterile water is used, and the plates turned upside down to avoid difficulties from condensation on the lid. Incubated usually at 20° C.

4163 I am anxious in the name of the Commission to thank you very much indeed for this most valuable evidence. I think we all agree it is of very great value indeed?—I wish I had had more time. Mr. Willis only gave me very short notice; I put it together rather hurriedly.

4164. I should just like to ask you one point about storm water. Are you of opinion that all storm water should go through the filters or not?—Go through filters?

4165. Through the filters; where there are bacteriological filters, do you think that all the storm water should be passed through them, or not; or have you not studied that point?—Well, I have studied that point. It depends entirely upon what you are aiming at. I think if you pass storm water through a filter bed at a great rate you will not get the same result of course, as if you were passing the normal quantity through a filter bed. If the storm water has been sufficiently diluted with rain water so as to be satisfactory to the Rivers Board or the authority controlling the water, then I think that that might be passed into the river without passing through the filter bed.

4166. You would be inclined to think that the storm water was injurious to the filter bed?—Not injurious to the filter bed, but it does not give the same result going through quickly as if it went through slowly.

4167. No; but if it does no harm to the filter bed what is the harm of its going through it?—None, that I can see.

4168. You do not think that it would wash away the colonies of bacteria or anything of that kind?—Not in the filter bed; it might in the septic tank.

4169. But not in the filter bed?—Not in the filter bed.

4170. Then may I ask whether you have any experience of the land treatment of sewage?—Yes. I know a good many sewage farms, and I have done a good many analyses in connection with sewage farm effluents.

4171. Do you consider that any soil can purify sewage when the land is frozen?—When the land is frozen?

4172. Frozen?—It will not pass through the land if the land is frozen before the sewage reaches it.

4173. Then the land will be useless for purification purposes?—Quite so.

4174. Have you ever watched through any prolonged period of cold weather what does happen on a sewage farm?—No; I am afraid I have no information upon that point.

4175. Can you give any approximate idea of the quantity of sewage per acre that could be properly treated by land treatment?—I think that depends a good deal upon the character of the soil, its porosity, and the subsoil, whether it is efficiently drained, and the way in which it is applied to the soil.

4176. There is no definite law?—There is no definite law; no.

4177. And would you say that any purification of sewage is possible where the land is water-logged?—No; certainly not, for the same reason that it is no use in time of frost.

4178. Have you ever known the soil of an old sewage farm to have been analysed bacterially?—No; I have no bacterial analysis. I have made chemical analyses of soil which has been used for sewage treatment.

4179. But not bacteriologically?—No.

4180. And have those chemical analyses shown any remarkable results?—No; I have noticed an accumulation of nitrogen in such soils, and also soils which originally were non-calcareous, and little or no lime in them, increase in efficiency with a certain quantity of lime; as lime increased, brought down by the sewage on to the farm, then that farm land gave better results, and I think that was shown also in the last report, the Rivers Pollution Report, in the analyses of soils then made by Sir Edward Frankland, although it did not seem to be recognised by him at the time that the quantity of lime in the soil influenced the amount of nitrification, and, of course, you can convert a non-calcareous soil into a calcareous soil by treating it with sewage which contained lime for two or three years; you give then the necessary lime for this efficient nitrification.

4181. Should you say that pathogenic organisms might survive land treatment of sewage?—I think it has been proved that with water passing over land, the filtrate from such land does contain pathogenic organisms in certain cases. Take the Maidstone example, I suppose one could regard it as an illustration; since the liquid passing through the land subsequently, probably caused the outbreak.

4182. Should you say that it was as likely that pathogenic organisms might get into a stream after passing over land, as that they might do so after passing through one of these bacterial filters?—Yes, quite so, the two things are exactly comparable. If a sewage farm works badly then pathogenic organisms can go through that sewage farm: if a filter-bed is working badly, then pathogenic organisms will go through that filter.

4183. But if the filter and the farm were both working well?—The results are similar in each case.

4184. You would say that the danger in the one case was as great as in the other?—Yes.

4185. And no greater?—If anything it is in favour of the filter, I should think, because it is more under control.

4186. Now, would you be prepared to say generally, that artificial filtration is in all respects as satisfactory as land treatment?—Undoubtedly, I say it is better.

4187. (*Professor Ramsay.*) I should like to take your evidence in the order in which you have given it, Dr. Rideal. Referring to the term organic nitrogen?—Yes.

4188-89. What does that mean?—Well, that is Kjeldahl nitrogen less the nitrogen of the free ammonia.

4190. Then you said in answer to question 4132, that samples for analysis should be collected proportionately to the flow, and not in equal quantities as is often done. How is this to be done, and what difference does it make when a short calculation will show the proportion of the sample collected to the flow? Is it not meant that the sample should be stated in terms of the total sewage instead of any definite volume of the sewage?—That depends again entirely on what you are trying to get at. That answer of mine was meant to apply to samples from a filter or samples of sewage from a town. If you take a single sample at any particular time that does not represent the average composition of the sewage of the town; if you take a single sample from the filter at any particular time, that does not represent the average composition of the liquid from that filter. The curve (exhibit A) that has been put in in one of these questions perhaps will answer that point better. I am afraid I have only two of these, but I have drawn a red curve.

4191. The red curve shows the volume discharged?—The red curve shows the volume discharged from that particular filter, and you notice that if you take samples at equal times you get varying amounts of nitric nitrogen. The black lines represent the quantities of nitric nitrogen discharged from the filter in parts per 100,000. The base line represents the time of discharge, 2, 4, 6, 8, 10 minutes, the filter emptying completely after about 40 minutes—about three-quarters of an hour. This is one of the Exeter filters, and I wished to find out whether the nitrates were coming away uniformly, and therefore I took samples every two minutes right through a complete discharge, or rather four complete discharges, and plotted them out in these curves. You will notice from the character of the black lines that they are irregular, and I should like to refer to this later on when we come to deal with the changes taking place in the filter, that it is not an uniform line, a straight line; the quantity of nitrate is different at different times. Now, if you want to determine how much nitric acid is being produced by this particular filter you must take it proportionately to the flow or you will get misleading results. Now the flow, the discharge of this filter is shown by the red line, and supposing we elect to take a sample (after five minutes or six minutes), you will find that after six minutes the red line shows that 3,500 gallons have been discharged out of this filter, which discharges normally a total of 8,000 gallons, therefore the quantity that has gone out after six minutes will be about one-third of the total quantity discharged by that filter. Now the nitrate determinations before that point, if you take this particular discharge, which was after a

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period of rest, and therefore is not a normal one, you will find that the nitrates were 2 running down to 1·25, but that after that period——

4192. (*Professor Foster.*) What does well flow mean?—The well is a well at the side of the septic tank filter.

4193. Then these mean?—These are taken from the discharge, not from the wells.

4194. Quite so, but from several filter beds; they are five filter beds?—No, from one filter bed; each line represents from one filter bed.

4195. Yes?—The discharge is controlled by the wells. The well discharges, then a particular filter discharges. Therefore, after six minutes, the average quality of the discharge has been reduced from 2 down to 1·2 of nitric nitrogen. Now, the filter goes on discharging for forty minutes, so the next thirty-four minutes you have the quality of the discharge varying from 1·2 down to as low as ·55. The two-thirds, therefore, of the discharge will have an average composition of somewhere between ·5 and 1·12, and one-third of the discharge has a composition between 2 and 1·12; therefore, if you do not take samples proportionately to the flow you will get an erroneous result. Now the way in which the nitric determinations published in connection with Exeter, and were given in the inquiry, were taken, in order to get over this difficulty was as follows:—The samples were taken after 1, 3, 6, 10, and 20 minutes after the commencement of the discharge, and those times you will notice correspond to times when equal volumes have come out of the filter and not after equal intervals of time. The same is true of course with regard to sewage discharged from a town. In the particular question you are referring to (Question 4131) the six samples were taken proportionately to the flow every hour from 6 a.m. to 6 p.m.

4196. (*Professor Ramsay.*) Yes, I see; then what you argue in favour of is that very frequent samples must be taken?—Proportionally to the flow.

4197. And would you state the results on the basis of the total amount of sewage passed during twenty-four hours?—Oh, it does not matter what the volume is; you multiply by the quantity, and then you get the total quantity.

4198. You think that would be the fairest way, then, of stating the analysis of sewage and the analysis of effluents in terms of the total quantity of sewage that has flowed?—Yes.

4199. From the whole town?—Yes.

4200. Can you explain what the meaning of these descending nitrates is; do the anaërobic bacteria cease to work?—In this curve?

4201. In that curve?—You will notice that there are altogether four analyses given in this table. The first one, the dark line, that is really the second one; the top one is the dark line, the dark line refers to a filter which had been kept empty for some days, and, therefore, had been well aerated, and you will notice that that is the only one really which shows a downward curve beginning with a very large nitric nitrogen for such filters, 2, and finishing with about 1. I explain that by saying that the nitrification has taken place during the resting period and the dribble, the draining during the resting period goes to the bottom of the filter, and, therefore, is the liquid which comes out first, and you will notice in that particular case is the richest in nitrate. Now when a filter has not had that long period of rest you do not notice that characteristic; but you notice in the last two—that is, the third and fourth especially—that it begins low and ascends, and I explain that by saying that the filter not having had a long resting empty period, has not produced a large amount of nitrate, and the bottom liquid that comes away is, therefore, poor in nitrate; but it increases as the discharge takes place, because the upper layers of the filter during the period of resting full have been nearer the air, and more oxygen has been in contact with the liquid and, therefore, the nitrates are richer at the finish.

4202. Do you regard such a filter as sufficiently able to aerate after discharging? Is it not probably the case that it fills up with carbonic acid very quickly?—I have put in some figures, I think, showing the quantity of carbonic acid. The amount of carbonic acid increases very rapidly.

4203. And does not get removed, I fancy?—I do not think so—I do not see how it can until it is filled up again, filled up with fresh liquid, so that they are unfavourable really for nitrification.

4204. Would it be advisable to blow air through them, or to expose them in some way to air?—Yes, if air was blown through you would bring more oxygen into contact with the organisms residing in that filter.

4205. (*Colonel Harding.*) Would there not be a current through the air valves through the filter during the empty period?—Carbonic acid is a very heavy gas; it remains down at the bottom of these filters much in the same way as it does in the brewery vat.

4206. But in this case the valves would remain open?—Yes, but the whole of the bottom of the filter is not a valve.

4207. (*Professor Foster.*) Do I gather, then, Dr. Rideal, that you think that the nitrates which are present in these effluents are nitrates formed during the previous periods of rest, simply washed out from the filter?—During the period of rest, quite so.

4208. And not during the flow itself?—Not during the full period.

4209. (*Professor Ramsay.*) Then a little further down; pass on to the next question, 4133. You say the nitrate would be reduced to nitrite, and this to nitrogen, according to reactions we shall consider later, and the liquefaction and hydrolysis change will proceed?—Yes, I have actually proved the production of nitrite from nitrate in such liquids, and I have also proved a loss of nitrogen—a loss of total nitrogen.

4210. Amounting to what? Can you give us some suggestion as to how much?—Well, very frequently one finds in comparing the quantity of nitrogen in the fresh sewage and the final sewage, perhaps one-half of the nitrogen has gone.

4211. Passing next to the table on the fermentations of organic acids, I suppose you would say that alkalinity is favourable to such fermentation?—Yes.

4212. And that strong acidity hinders it?—Strong acidity, certainly yes.

4213. Have you made any experiments as to the amount of alkalinity which would be favourable, or the amount of acidity which is unfavourable?—No, I am afraid I have not.

4214. These experiments could be made, of course?—Yes.

4215. And would they not throw some light on the value of liming the sewage?—Well, all sewage, unless it is contaminated with manufacturing refuse, is alkaline, slightly alkaline, and that seems to be a condition which is favourable, sufficiently favourable for this change to take place.

4216. Sufficiently alkaline, do you think?—Yes, excessively alkaline is unfavourable. Undoubtedly an alkalinity above 40 to 50 parts of ammonia per 100,000 is unfavourable.

4217. Then do you regard the chemical treatment with lime as unfavourable to future fermentation?—I am certain from the results that the absence of nitrification after lime treatment has been due to a sterilising action—that has been met with over and over again during the last few years.

4218. Then you speak in your answer of the order of operations which may go on in a bacterial filter, and you say that any mixing or confusion in the order, any artificial interference, or attempt to work distinct reactions simultaneously in the same receptacle will lead to uncertainty and irregularity in the results?—Yes.

4219. Putting that sentence into facts, would you argue that such a filter as Mr. Dibdin's is defective in so far as it tends to mix up those reactions?—Yes, that is the object of that sentence really, yes.

4220. But you say, I suppose, that such a filter as the Exeter one, or as Colonel Ducat's one, is a single-action filter?—Yes, both good. Well, the Exeter filter has the same objections as Dibdin's filter, because there is the resting full period. You are on the septic tank now, I suppose?

4221. The septic tank, yes. I suppose, as a deduction from that statement, you would say if it is decided to treat the sewage anaërobically, the right thing would be to do both as absolutely separate operations, to make use of some such septic tank as the Exeter tank, and follow that up with thorough aeration?—Yes.

4222. A completely separate operation?—Yes.

4223. You refer to the Scott-Moncrieff apparatus; do

you regard that as a mixture of operations, or as separate operations—to separate the aërobic from the anaërobic fermentation?—In the Scott-Moncrieff apparatus, the first part is distinctly anaërobic; in the filter the upper trays are mixed, the lower trays are purely nitrifying, and carbon oxidizing.

4224. Then do you regard that arrangement as satisfactory from your point of view?—I think that it is a very good one.

4225. Would it be possible to arrange the Exeter filters in such a way as to cause the filtrate to descend from the one to the other, and suffer a nitrifying change in each as it proceeds in the same way as the filtrate in the Scott-Moncrieff system descends through several trays, and suffers changes in each?—Yes. If you will replace the present filter beds at Exeter by some of Scott-Moncrieff's trays, or by a Ducat filter, you will get more nitrification, and do away with the resting period, and work it continuously in the same way as a septic tank works continuously.

4226. My point was rather this: Would anything be gained by separating the filters at Exeter into several series and causing, say, partial anaërobic fermentation to take place in the first, more nitrification to take place in the second, and final complete nitrification, say, to take place in the third?—Yes, if you passed the liquid through five filters instead of one, you would improve the effect.

4227. You would separate the organisms by doing so?—I think so, because in the second and third, and subsequent filters, they are protected from the anaërobic organisms which issue from the slotted pipe and go on to the top of the filter. Well, if after passing through that filter it goes on to a second filter, that second filter will not become contaminated with anaërobic organisms from the septic tank, in the same way as the first filter, and, therefore, the breed in the second filter will be a purer breed than in the first filter.

4228. You state a little further down, in answer to question 4140, "The action is more energetic when the products are removed as formed, and the bacteria are supplied with fresh food." That is perfectly true, but is neutralization removal? For example, does excess, or addition of alkali promote complete change; you are speaking of the change from maltose into glucose?—Yes.

4229. And if the product is removed, we all agree the action would be more energetic; but would neutralization of an acid come to the same thing as its removal?—That might be, yes. In this particular case, of course, if you have organisms, producing alkalinity, converting the nitrogen into ammonia, if that ammonia gets above a certain amount, then the action will cease; if that ammonia could be neutralized, but I do not quite see how it could be done practically, the change might still go on.

4230. Then in your answer to question 4141 you point out that "In methods involving a 'resting full' and 'resting empty' period, there is alternate inversion of bacterial action between aërobes and anaërobes, with a disturbance of both, necessitating prolonged periods of rest." Has that been proved or is it a pious opinion?—I think the Leeds experiments show that in the last report.

4231. Could you give us any detail about those?—Well, it is only second-hand information about it. I have read a report very carefully about them, and Colonel Harding is here.

4232 Perhaps Colonel Harding may have something to say on that?—Perhaps.

(*Colonel Harding.*) I did not catch the question,

(*Professor Ramsay.*) My question is this: I quoted Dr. Rideal, "In methods involving a 'resting full' and 'resting empty' period there is alternate inversion of bacterial action between aërobes and anaërobes, with a disturbance of both, necessitating prolonged periods of rest?"

(*Colonel Harding.*) I am afraid the bacteriology of the experiments at Leeds has not been sufficiently studied to enable me to offer an opinion?—There is one point which I noticed in that report, which rather, to my mind, supports that conclusion, and that is that in one experiment in which there was a very long period of rest, and the filter when filled practically regained its original capacity, yet it lost that gain very rapidly after the long period of rest.

4233. (*Professor Ramsay.*) What would you argue from that?—I argue from that that the long period of rest had killed or arrested the activity of the anaërobes, and therefore when the filter was refilled these organisms were either not present or unable to deal with the incoming solids in the same way as they normally did, and, therefore, a longer period was required in order that the filter might work satisfactorily.

4234. Then that practically is an enlargement of your answer to question 4142?—Yes.

4235. Towards the end of the answer to question 4148 you state that chlorine is an agent which will finally purify an effluent. I should like to ask you whether you think that is an advisable thing to completely kill out the organisms in an effluent?—No, certainly not, but a great point has been made recently about the presence of pathogenic organisms possibly in such filters, and I suggest that this is a means of getting out of that difficulty if it really existed.

4236. That is to say if the effluent is to be used for drinking?—Yes.

4237. Then as regards the cost of such a method would it not be prohibitive?—I am not concerned with the cost at all. I do not believe it would be very costly from the experiments we made at Maidenhead.

4238. But it would only be applicable where the water was intended to be drunk?—I should only advise it in such cases.

4239. Then in the next answer, 4149, you speak of nitrous acid being an unstable substance, and you pass on to say "From this useful instability they count (nitrous acid and nitrates count) in many analyses in the 'oxygen consumed,' and therefore lead to a higher estimate of the organic matter." I suppose you refer to Roscoe's and Dibdin's plans of treating with permanganate?—Yes.

4240. Then you hold this process as consequently in error when there are nitrites present?—Nitrites always increase the oxygen consumed unless there is a reduction for the three minutes' test.

4241. Which practically destroys nitrites?—Yes.

4242. In the answer to question 4150 towards the end you say that the denitrifying bacteria will not develop in liquids deprived of nitrate and out of contact with air, nor will they attack organic matter under these circumstances. Do you refer here to Adeney's process for adding nitrates artificially to the effluent?—I do not think it makes any difference whether the nitrates have been added artificially or whether they exist already formed in the sewage.

4243. Then you regard their existence in the sewage as advantageous?—Yes, nitrates.

4244. Nitrates?—Undoubtedly, for this reason—

4245. Because they are able to give up oxygen later on?—Later on by the denitrification process.

4246. The amount of carbonaceous matter requiring destruction is measured by the ordinary figure of oxygen absorbed as determined by permanganate, since after four hours' heating with permanganate no dangerous matter can be left. Has that been proved, or is it matter of opinion?—It is only a matter of opinion.

4247. It would depend, of course, upon the quantity of permanganate?—I see your point. I am assuming there, the ordinary method of adding permanganate in excess—permanganate added in excess.

4248. That, of course, would destroy—we agree, I suppose—would destroy bacteria; but would it destroy substances which are finally fermentable? Would it destroy ptomaines?—Well, there must be some organic matters left after that treatment; but I do not think there would be any of an injurious character.

4249. It has not been proved, however?—I am afraid I am obliged to ask you again the meaning of the Table giving terms which I suppose show the progress of the change of nitrogen in the different trays of the Scott-Moncrieff filter?—These are the curves that accompany. (*Exhibiting curves.*)

4250. I have not seen those?—There are several copies of them.

4251. You give in the first row the chlorine present in the water, then next nitrogen as nitrite. Is there any nitrogen as nitrite in the Garfield domestic filter?—These tables of comparison are not my own analyses except so far as Cameron at Exeter and Scott-Moncrieff are concerned. Those figures are the figures which I have taken from reports and information which have been given me with regard to Garfield and Sutton, and I could not find the nitrite and nitrate given separately for the Garfield filter. There is nitrite and nitrate there; it is given in the last line.

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4252. In the last column; the summary of the two. Then you argue from this Table that the nitrification is much more complete in the Scott-Moncrieff filter?—Yes.

4253. Than in any other plan?—Than in any other plan; yes. The curves will show that production of nitric nitrogen in the Scott-Moncrieff trays better.

4254. You give two tables again. What are we supposed to learn from those tables?—The first table shows denitrification taking place with loss of nitrogen, and the conversion of the ammonia into nitrite. You will notice the nitric nitrogen is diminishing from 10 to 7·06, also the organic nitrogen is diminishing at the same time from 2·89 to 2·38, which is the reaction we were discussing just now. At the same time you have the ammonia being converted into nitrite, so that you have denitrification taking place with nitrosification.

4255. Organic nitrogen, if I understand rightly, is Kjeldahl nitrogen, ammonia, nitrites, and nitrates?—No; total Kjeldahl nitrogen less free ammonia. That shows the loss of nitrogen in the experiment—actual proof of the loss of nitrogen from a sewage.

4256. That there is a loss of nitrogen as nitrogen or as nitrous oxide?—Yes, the second one you asked me was. It shows nitrosification; in the same way the free ammonia is diminishing slowly with the production of nitrite with a loss of organic nitrogen.

4257. Has the loss of nitrogen as nitrous oxide been proved in any way?—I have never found nitrous oxide, but I have found loss of nitrogen without the production of free nitrogen.

4258. A loss of nitrogen?—Without the production of free nitrogen. That is so, without the production of a gas, and it has gone out of the solution in the form of nitrite, nitrate, free ammonia, and organic nitrogen, so that there is a nitrogenous substance there which is not determined by either of those four methods.

4259. Which you regard as nitrous oxide dissolved in water?—Dissolved in water, probably, Gayon and Dupetit found nitrous oxide.

4260. You again speak of the standards of purity and methods of statement of analyses—would it be fair to state the analyses in terms of the total chlorine or would that be a risky thing? Is the chlorine in sewage sufficiently constant to make it a basis for the statement of analysis?—I think so; as a general rule it is. If you make the allowance for the chlorine in the water supply of the town, and you have satisfied yourself that there is no manufacturing chlorine of any serious character introduced.

4261. Then you think analyses would be much more readily comparable if they were referred to total chlorine?—Yes. I am quite certain that in a raw sewage the nitrogen as a rule approaches that of the chlorine, and is often a little higher than the chlorine, and I have always very grave doubts about an analysis if the nitrogen is much lower than the chlorine.

4262. Do you regard a statement of albuminoid ammonia or of oxidisability with permanganate, oxygen absorbed, by itself as of any great value?—Oh! none whatever, I think.

4263. It really shows nothing; it may show nothing?—It shows the absolute amount of the substance there.

4264. I refer to a sentence here, in which you say: "I have noticed that many dilute putrid sewages of offensive character have shown less albuminoid or organic nitrogen than the condemnatory limits of existing standards"?—Quite so.

4265. Do you consider that the process of analysis is wrong, or that the sewages may contain very small amounts of albuminoid ammonia, and still be very offensive?—Yes; quite so.

4266. Which?—I mean both. Albuminoid ammonia is a very unsatisfactory method, and the result when you have obtained it is of little value for that reason, that you may have a liquid containing a very small quantity of organic matter in the form of albuminoid ammonia, which is below these standards which have been put forward by different authorities, and yet that liquid may be of a most dangerous character. For example, if you have a liquid containing less than ·1 of albuminoid ammonia, and that albuminoid ammonia is derived from cholera germs, or the products of cholera germs, it is far more dangerous than if it is some peptone from a meat extract.

4267. Then, a little further on, you say: "The multitude of bacteria in sewage is so enormous, and their character so various, that a mere counting of their numbers must be unnecessary and inaccurate;" do you adhere to that opinion?—Well, that is very badly worded.

4268. Would you attach no importance to the actual number of bacteria in an effluent?—No; the actual number I think, in the same way as the absolute amount of albuminoid ammonia, is of little value from a standard point of view. From a scientific point of view it may be of immense value, but from a standard point of view the number is of no value at all; it is the character of the organisms, and so I suggest there that a ratio is far more important than the absolute number; it is the ratio of the pathogenic forms to the non-pathogenic forms that should be the standard fixed upon rather than the absolute amount of either.

4269. I should like to pass on to a statement in which you speak of Dr. Dupré's test, to enclose an effluent in a bottle and determine the free oxygen present before and after keeping?—Yes.

4270. You also say: "Unfortunately, although the actual work of this test can be carried out in a few minutes, the sample had to be allowed to stand for five or ten days." But is that an unfortunate thing? Would it matter if the effluent was analysed after five to ten days, do you think?—Well, it is unfortunate that the test takes so long before you can report upon the quality of a liquid.

4271. But if you issue a good report is not that more important?—It is always desirable, I think, to ascertain the dangerous character of these liquids as soon as possible.

4272. What I wish to get at rather is, would it be a test which could be applied by someone not skilled in chemistry; would it serve as a reasonable test for a workman to carry out?—I think so.

4273. Even though he had to wait ten days for it?—I think so.

4274. So after that regular sewage purification process tests of this kind might be made continuously?—Yes, but you would have to wait five days; it would take you five days before you could correct the error, if any, in the process. You want really a quick test, so as to know at once what alterations to make.

4275. Have you any quick test to suggest?—Well, I suggest the ratio of the nitrate to the organic matter, organic nitrogen.

4276. That of course takes something that involves a day's work?—Yes; the absolute amount of nitrate, of course, can be determined in two or three minutes, pretty quickly on the spot if you are watching the process to determine the nitrate action.

4277. By means of indigo?—By means of indigo.

4278. But the Kjeldahl always takes some time?—That takes some time, and of course the ratio of the nitrate to the oxygen consumed is very quick—three or four hours.

4279. Further on you speak of the Wanklyn test, and do you notice that distilling albuminoid ammonia frequently with water converts it into free ammonia?—Yes.

4280. You state also that "the majority of analysts employ the original Wanklyn with preliminary dilution; hence the published results almost invariably show too much free and too little albuminoid ammonia"?—Yes.

4281. You regard that as correct?—Yes.

4282. Might I ask how you estimate chlorine?—Usually by evaporation to dryness, taking up again with water, and then using silver nitrate and chromate as an indicator.

4283. What is the advantage of evaporation to dryness?—Sewage is frequently very alkaline, then the chromate indicator does not respond.

4284. Have you noticed that in evaporating down, albumenoids decompose with loss of ammonia?—I should think it is very probable that with a dilute solution of ammonium chloride, the ammonia would come off.

4285. Would not that alter the chlorine, too; would not the chlorine disappear also in the same way?—Well, usually the sewages contain a quantity of soda, which gives it an alkalinity sufficient to neutralise that, and I think the greater portion of the chloride is in the form of sodium chloride and calcium chloride.

2486. (*Professor Foster.*) I do not know that I quite understand the view that you take about the anaërobic and the aërobic organisms. You think it is necessary that

there should first be an action of the anaërobic organisms succeeded by the action of the aërobic organisms?—Yes.

4287. Is that because the so-called anaërobic organisms can do what the aërobic organisms cannot do, or because they do it better? I ask that question because I see that you quote with approval a remark of Hering's of Massachusetts, in which he draws a distinction between the action of these organisms on solid matter and on matter in solution. I gather from your quotation of him that he thinks the aërobic organisms can carry out the complete change provided the material is in solution?—That is his view. yes. I believe that the anaërobic change is a necessary preliminary very largely from a chemical consideration that the breaking down of these organic bodies takes place without the absorption of oxygen, without any chemical addition to the substance; you have a breaking down of the organic matter by the organism to ammonia and to marsh gas or to carbonic acid, but that oxygen from the carbonic acid is not derived from atmospheric oxygen, but from hydrolysis; the changes are hydrolytic changes, and therefore they are brought about by organisms which are acting anaërobically; even if they are aërobes the oxygen is not concerned in the change. In the same way as yeast: although yeast is an aërobe, it does its work best in vacuo or in the absence of air at the bottom of the vat.

4288. But with regard to this quotation from Hering, have you any knowledge of the evidence existing that the anaërobes act so specially successfully with solid matter as compared to the aërobes, or let us not say aërobic organisms, but organisms acting under aërobic conditions?—I have found very rapid solvent action from both aërobes and anaërobes, but the change does not take place by means of the air.

4289. That was not quite what I meant. Then you do not agree with what Hering says there. Organisms working under aërobic conditions can readily liquefy solid portions of the sewage?—So he says.

4290. Yes?—He says they do it, but not at the same rate as anaërobes.

4291. What is your view on that point, or what is his evidence?—I am afraid I cannot quite follow your question.

4292. What evidence is there that organisms working under anaërobic conditions dissolve the solid matter of the sewage much more rapidly than organisms working under aërobic conditions, and on the contrary that when the matter is in solution the aërobic organisms on the other hand work the more successfully; what is the evidence of that?—Well, we have the evidence of Exeter and the Scott-Moncrieff upward filter, and upward filtration experiments showing the solvent action on organic matter under deficient oxygen.

4293. I mean this; there can be no doubt that you may get solution of the organic matter under anaërobic conditions, but what is the quantitative proof that that solution takes place much more rapidly under those conditions than it would under aërobic conditions?—The old experiments of twenty years ago on upward and downward filtration establish that, I think.

4294. But with regard to that let me quote the evidence of Dr. Dibdin. He says that his filters work entirely under aërobic conditions, and that he gets complete and rapid disappearance of the solid matters in the sewage as well as the change of the matters in solution?—Yes, but those filters are not continuously aërobic; they are filled and resting full at different periods, and samples of liquid taken from such filters a short time afterwards will show no free oxygen in the body of the liquid.

4295. The solid material is destroyed, is it not, in the filter?—Yes.

4296. Your argument is that that solution takes place in the middle of the resting period?—Yes.

4297. When the oxygen which was introduced into the bed in the empty period has been used up?—Yes.

4298. Have you evidence of that?—No; I do not know that I have evidence of that.

4299. Well, then, it has been stated that if sewage containing solid matters in suspension be simply allowed to trickle through a bed of cinders complete solution will also take place; that is under aërobic conditions, is it not?—Yes.

4300. And take place very rapidly?—Yes.

4301. And completely?—Yes; that finely comminuted sewage matter will disappear, go into solution, or oxidise into carbonic acid; I do not think it goes into solution at all; I think it goes into carbonic acid.

4302. Does it depend on the size of the material?—No.

4303. You said "finely comminuted," which refers to size only?—Yes, but that expressly refers to earlier material which has a different character from the original—

4304. Why do you speak of it as "finely comminuted"; what is the point of "finely comminuted"?—Because when I see that material in sewage I know that it has undergone this hydrolytic change from the analyses, you always associate it with a large quantity of ammonia, for example, a fresh sewage will contain a small quantity of ammonia, and then you do not get this comminuted white matter; you get then the sewage in fœcal lumps, and therefore I think I am justified in saying that this finely divided matter is in a different condition to the original matter from a chemical point of view.

4305. This is the statement; what is called crude sewage may be thrown upon, let me say, a heap of cinders?—Yes.

4306. The material slowly trickles through the heap, and therefore we presume that the action may be spoken of as one taking place under aërobic conditions, and the whole of that crude sewage is disposed of?—Yes, slowly, I agree.

4307. I do not think the term "slowly" is necessary to be used. By the time the sewage has got through the material all the changes have been accomplished?—Well?

4308. The larger portions have been broken down, and the smaller portions have undergone the necessary changes, whatever they may be, leading ultimately to nitrification?—Well, I have never seen any results showing the complete conversion of the organic matter in a crude sewage into nitrate by such a process.

4309. That has been stated to us as taking place?—Yes; I have never seen any analyses that justify me in believing that.

4310. Is our knowledge very complete about the action of these anaërobic organisms and the aërobic organisms?—We are only beginning.

4311. I see you give a list?—Yes.

4312. Of the bacteria occurring in sewage?—That is a working list.

4313-4. It is gathered from various authorities, is it not?—Yes.

4315. And the definite anaërobes, obligatory anaërobes, are six in number?—Yes.

4316. The facultative are a very, very long list?—Yes.

4317. Do we know adequately; have we adequate information concerning the action of these facultative anaërobes and aërobes as to the changes they bring about, even under so-called aërobic conditions to justify one in stating that before the final changes in the sewage take place there must have been anaërobic changes. Or to put it in this way: do we know sufficiently about them to assert that it is absolutely certain that the anaërobic phase must precede the aërobic?—I do not wish to press the anaërobic phase, the anaërobe more than the aërobe, except so far as from the chemical changes that take place. For example, I have given somewhere the change that takes place with an aërobe upon gelatine. There has been no oxidation effect, but the breaking down of the gelatine has gone through the albumose and the peptone stage and the extractive matters have been produced by this aërobe without any oxidation taking place in those changes.

4318. My point is rather this. The tendency of your evidence is to show that in constructing any arrangement or apparatus for the disposal of sewage it is necessary that it should consist of two parts, of the preliminary anaërobic part and the subsequent aërobic part, and my point is that we have had evidence brought before us that the whole of the change may apparently take place under conditions which cannot be spoken of as anything else but aërobic since there is plenty of access of air?—Yes.

4319. From your experience and from your knowledge, have you anything to say which would render it *a priori* impossible that that should be the case?—No.

4320. That with the multitude of organisms which are present in the sewage and the extreme complexity of the changes which take place, the possibility among other things of one organism sheltering another?—Yes.

4321. We had instances brought before us by Professor Marshall Ward of the possibility of anaërobic organisms

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and aërobic organisms working together in concert, so to speak?—Yes.

4322. Well, all that points to the possibility of an arrangement being adequate for the complete disposal of sewage, for carrying out all the necessary changes, without the necessity of provisions being made for the first part of the changes taking place under purely anaërobic conditions?—Yes.

4323. And you think that is possible?—Yes.

4324. Although the general tendency of your evidence is in favour of always having an arrangement for an anaërobic phase?—Yes.

4325. You think the other is quite possible?—Yes. There is one addition I might make to your last question, and that is a thing that has often occurred to me in this connection, and that is urine itself. Urine itself is a product consisting of products which have resisted oxidation in the blood, and therefore have been under oxidation conditions and have been oxidised. All those products, the urea and other products in urine, have been under this oxidising condition and have survived. They are the products, and it would seem more likely that they would respond more easily to anaërobic change than to aërobic change. And we know that that is the case with colouring matters. The loss of colour takes place under reducing action—reducing conditions rather than under oxidising conditions.

4326. Well, it depends on the colouring matter, does it not?—It depends on the colouring matter; the colouring matters of urine will bleach under such conditions. That is only a theoretical point in connection with it.

4327. Yes, but in the sewage we have all these various organisms to deal with; happily they do not exist in the blood?—No.

4328. I was going to ask you as to your Table of fermentations of organic acids; is this the result of your own. Is it a statement gathered, or have you made any number of observations yourself?—No; this statement is as I give it from Dr. Herfeldt's paper.

4329. Have you made any observations yourself on the changes of these substances produced by organisms?—Yes.

4330. Have you used pure cultures and pure substances?—Well I have used pure gelatine.

4331. I mean with any of those acids or salts?—No.

4332. You have not?—No.

4333. You have no experience as to how the pure salts behave with regard to the action of the organisms as compared with impure salts or mixtures?—No.

4334. As to how for instance urea behaves towards micrococi urræ as compared with urine containing urea?—No.

4335. Then with regard to what you were mentioning to Professor Ramsay in respect to organisms in the effluent, you said it did not matter how many organisms there were in the effluent?—I said the quality is more important that the quantity.

4336. Yes, but the expression was rather stronger than that, was it not; that the mere counting was unmeaning?—Was unmeaning, yes.

4337. But surely it is undesirable that an effluent should be crowded with organisms?—I do not see why if they are all normal water organisms for example, they may be very useful lower down.

4338. I mean if you have a large population there will probably be some black sheep?—Yes.

4339. Until you have ascertained that they are all good men and true, you would think them undesirable?—I should not condemn it simply because there was a large quantity on the chance of some black sheep being amongst them.

4340. No, but if you have a very large number. If you take your effluent and that effluent is crowded with bacteria until you have ascertained that they are all perfectly harmless?—Until you have done that I think the counting is meaningless.

4341. You do not mean the counting itself is meaningless, but judged alone?—Yes, quite so.

4342. That is rather a different statement, is it not?—That is what I meant to imply in the first instance, in the same way that the albuminoid ammonia term alone is a meaningless term, so the absolute number of organisms in a sewage is a meaningless term.

4343. So that you think that the organisms in the effluent should be very carefully examined as to their nature?—I do not think that we ought to discharge pathogenic organisms from sewage works into rivers—no.

4344. That means that you think that there ought to be an examination of the effluent—a bacteriological examination of the effluent in order to see if there are any so-called pathogenic organisms?—Yes any new process should be very carefully studied with a view to see whether any pathogenic organisms escape.

4345. How do we define a pathogenic organism?—I am afraid I am not a medical man.

4346. Can they always be told by their morphological features?—No.

4347. And is it not the case that an organism may, under certain circumstances, be harmless, and under other circumstances become pathogenic?—Yes, I believe that is so.

4348. So that a bacteriological examination of the effluent is in your opinion very desirable?—For any new process certainly, until it is established that it is not producing pathogenic organisms.

4349. The real feature of the process is the diminution of the organisms which may previously have been in the sewage. The real beneficial action, with regard to organisms, of the apparatus is that the apparatus should not allow hurtful organisms to pass?—That is so, yes, and I think that by the alternative, by keeping it in two distinct stages, you insure that better than by trying to attempt the purification in one process.

4350. Have you any accurate information as to the destruction of these organisms during the process?—There was a very long and elaborate report by Dr. Pickard given at the Exeter inquiry on that very subject on typhoid organisms.

4351. I did not mean so much that. For instance, what becomes of the mass of the anaërobic organisms after the anaërobic phase of action is past and the sewage is subjected?—The majority of them remain behind in the first process apparatus.

4353. They remain behind?—Yes.

4353. And the rest?—The rest are arrested on the top of the first filter.

4354. And what becomes of them there, do you think?—They may go on doing some work, and some probably finding no food supply, die out.

4354*. (*Sir Richard Thorne.*) Professor Foster has asked you a great many questions that I had intended to ask you, but I should like to recur to some of them just to get a few more details from you. You made a remark in answer to a question by Professor Ramsay to this effect, "If a filter is working badly pathogenic organisms may pass through." Did you ever hear of a filter, however efficiently it was working, that did not allow pathogenic organisms to pass through?—It is a difficult question to answer. When I talked about a badly working filter, I meant that a filter working under conditions of bad aeration would be more likely to let pathogenic organisms through than under conditions of good aeration. If you mean by a pathogenic organism a coli organism, I believe a coli organism has been found in most of these filtrates.

4355. I was going to ask you what you meant by "pathogenic organisms"; whether you had limited them to specific bacteria as such, or whether you included spores—as of bacillus enteritidis sporogenes and several others?—No, the bacilli enteritidis sporogenes is an anaërobic organism, and therefore is not likely to survive a well aerated filter.

4356. I notice towards the end of your answer to question 4148 you say, "No pathogenic organisms were found in any of the numerous samples of Maidenhead sewage." Do you know that there were any in the sewage before the process of treatment was begun?—I think that is not my own work; that is a quotation from the late Dr. Kanthack.

4357. I notice his name now is at the head of it, but it is not in inverted commas, and, therefore, I did not know that it was his. Have you ever known any effluent at all that you could say was absolutely free from pathogenic organisms, including, for example, the bacillus enteritidis sporogenes. Has any test been made which has any sewage effluent whatever to be absolutely free from pathogenic organisms?—Absolutely free?—I do not think an effluent absolutely free from pathogenic organisms has been secured under any conditions. I have no evidence myself, and I do not remember seeing any by any one.

4368. Well, has any determination whatever been made as to the number of pathogenic organisms in ordinary sewage effluents?—Yes, I think there is Dr. Cartwright Wood's and Dr. Sims Woodhead's work in connection with the Exeter inquiry.

4359. At a time when they knew that pathogenic organisms were entering the sewage?—Yes, the original sewage gave these reactions when inoculated into guinea-pigs, and then the effluent from the septic tank gave these reactions with guinea-pigs and rabbits, but the effluent from the filter bed, no.

4360. Then we come back to the question what are pathogenic organisms?—Yes.

4361. Because their action with a guinea-pig is not proof of pathogenic microbes?—No.

4362. Bearing upon that, Professor Foster was asking you the value you attached to the number of organisms in a cubic centimetre of an effluent?—Yes.

4363. And you said that the number was unmeaning. Now I will take an actual instance. Here I have before me a crude sewage, which contains per cubic centimetre over 4,000,000 organisms?—Yes.

4364. The filter effluent after sewage precipitation and passing through a tank and then through a filter—the ultimate effluent only contains 45,000. Should you attach any importance to that or none, the diminution from 4,000,000 down to 45,000?—Well, if you tell me it has gone through a filter, I should say that the 45,000 is obviously better than the 4,000,000; but if you give me one liquid containing 45,000 organisms, and another liquid containing 4,000,000 organisms, I should not be able to say which was the better of the two from simply knowing the number of the organisms.

4365. But I suppose you would admit that there must almost necessarily be certain harmful organisms in sewage?—Yes.

4366. And therefore the mere reduction from 4,000,000 down to 45,000 in itself, must it not be a definite advantage?—Oh, I think so, undoubtedly. That is the same liquid; if the same liquid shows a diminution in the number of organisms, then that is an improvement on the liquid.

4367. Then your statement only refers——?—To two different liquids the sources of which I do not know, the one containing 45,000, and the other containing 4,000,000; I would not say whether the one containing the 45,000 was better than the one containing the 4,000,000 in the case of two liquids supposed to be mixed with sewage, or which have not gone through a process.

4368. Well, now is it possible that the diminution in a given instance, say, from 4,000,000 down to 45,000, may do harm by removing a large number of organisms which would continue their work for good in the stream?—Yes.

4369. And from that point of view the mere counting of heads, so to speak, is of no value?—I have already said that counting heads is meaningless, unless you know the value of it.

4370. But I mean in the same sewage?—Well, it would depend upon the character of the liquid. If all the organic matter had been consumed, and it was a well nitrated liquid with no more work for the organisms to do, then their number does not signify very much. I attach a good deal of importance to the number of blood heat organisms; the ratio of the blood-heat organisms to the total number is more important than the absolute number of either. All heat organisms being capable of growing within the body are, therefore, organisms which may have pathogenic characters. Organisms which do not grow at the blood heat are organisms which are not pathogenic presumably.

4371. No, but the typhoid organism, for example, will grow for years in the soil out of doors?—Yes, but it will grow at blood heat.

4372. Yes, but it will grow and multiply outside the animal body?—Yes, but in the analysis in counting it you count the number of organisms that grow at blood-heat, you insure in that number all the pathogenic organisms.

4373. Well, I notice in your answer to Question 4142, you speak of certain organisms which finally disappear. "Such is the fate," you say, "as a rule of pathogenic organisms, which preferably grow at blood heat." Now may I ask if this is an assumption that they finally disappear, or have you actually made experiments as to that? No, I base that upon the experiments of Dr. Sims Woodhead and Dr. Cartwright Wood, to whom I was referring just now, and also Dr. Pickard's very elaborate experiments on the survival of typhoid organisms passing through the septic tank, and also through filters.

4374. Even accepting those experiments, would that prove anything more than that they ceased from multiplication for a time; would it mean that they were killed?—No; it might only be arrested.

4375. Would you attach much importance to differentiating between organisms which do and do not liquefy the gelatine culture medium?—No.

4376. You do not?—No.

4377. You make a good many references in your evidence to rivers and streams; for example, in answer to question 4160, where you speak a good deal of the volume of the stream, what do you mean by a stream? Do you mean the black sewage-laden stream, such as we get in the North of England, or the trout stream?—I meant it to be a general statement.

4378. I know you have; but does not that vitiate your conclusion very largely?—I do not think so, because I have mentioned elsewhere that I attach a good deal of importance to the amount of dissolved oxygen in such a stream, and therefore, of course, with a muddy stream with a low amount of dissolved oxygen, you would require a greater volume of it to deal with an effluent discharged into it than if you had a pure stream well aerated, containing its maximum amount of dissolved oxygen.

4379. Then where you speak of the purifying action of river water you mean a river water that is free from pollution, I suppose?—No, because a river water containing only one cubic centimetre of oxygen per litre, instead of the maximum quantity of seven, would be able to deal with a certain amount of incoming organic matter—only one seventh of the amount that a well aërated stream would.

4380. The whole thing depends, then, upon your river being well aërated?—The total quantity of oxygen in the stream, yes. I give an illustration. The dissolved oxygen in the Thames at the outfall from Dibdin's figures—London County Council figures—are ·4 parts of dissolved oxygen per 100,000, whereas in the Exe, which is a known manufacturing stream, it is up to one gramme. Of course, it is obvious there that the two liquids would deal with different quantities of incoming sewage, even if they had the same volume.

4381. You were speaking just now of the bacillus coli, and in answer to question 4160 you say that only a low number of organisms of the coli group should be permissible. Why do you attach importance to the numerical amount of the bacillus coli in an effluent?—Well, of course, the amount there, is the amount of organisms capable of growing at blood heat, and the coli group grow at the body temperature, although they may not be absolutely deadly; they may have some effect for good or for evil.

4382. Do you do more than regard them as evidence of the effluent still containing something which came from the alimentary canal—from the large intestine?—Quite so, yes.

4383. In speaking of that, you refer to a question which I think Professor Foster asked you: "Absolute sterility in an effluent is at present out of the question." Do you mean because the effluent passes into a stream which is possibly abounding in bacterial life?—That is what I mean.

4384. Then you say it would not be advisable?—I say it is out of the question to have a liquid which is absolutely sterile for any length of time. The moment it goes into the stream it ceases to be sterile.

4385. But if you could make it sterile before it passes into the stream you would get rid of all the contained pathogenic organisms, and then there is no harm in it passing into a stream which abounds with organisms. You say, "Nor in general would it be necessary, or even advisable." Why would it not be advisable?—I go on to say, of course, if it is going into a well oxygenated stream—a stream well supplied with organisms—then any change which is necessary, complete final changes can go on; but if it is going into a cut or ditch, and is not going to be mixed with fresh water, so as to have a fresh supply of organisms supplied to it, then the sterility would arrest such complete final changes until such liquid obtained the necessary organisms by a mixture of water later on.

4386. I am thinking rather for the moment of streams which may be used for drinking purposes, and I was going to ask you this question: A stream which is used

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for drinking purposes would probably abound with organisms, would it not?—Yes.

4387. Would it not be a very great boon to have the effluent made absolutely sterile before it entered such a stream, because you then would be quite certain that you would add to it none of the pathogenic organisms from the sewage; you would leave ordinary fresh river water organisms to continue any work which remained to be done?—Yes, I think if anyone wishes to produce a sterile effluent, and would care to go to the expense, it could be done.

4388. Do you think it would be very costly?—In answer to Professor Ramsay, I think it was, I said I did not think it would be very costly in the question of chlorine. Chlorine reduces the number of organisms very quickly after you have removed the organic matter from the sewage, after the organic matter has been removed by a bacterial process, by means of the organisms, so that you have a very small quantity of organic matter left in the sewage; then an addition of chlorine to such liquid causes a very great diminution in the number of organisms. If you add the chlorine to a crude sewage, or a sewage which still contains organic matter, then that chlorine is absorbed by the organic matter, and you do not insure the killing of all the organisms to the same extent, so that a much smaller quantity of chlorine is required for a good filtrate than for a raw sewage.

4389. (*Professor Foster.*) Was the filtrate at Maidenhead a good filtrate?—No, it was bad.

4390. Was there not a remarkable destruction of organisms?—Oh, yes.

4391. Although the filtrate was bad?—Yes, but then we used large quantities of chlorine. Then it becomes expensive. You must keep the chlorine down as small as possible in order to make it practicable.

4392. I rather fancied from what the late Dr. Kanthack said one day that the amount of chlorine used there was remarkably small?—Yes.

4393. He was very much struck with the bacterial action of a very small quantity?—Yes.

4394. And that in spite of there being a very large quantity of organic matter in the filtrate?—Quite so, but they were bad liquids from our point of view now. They were purified sewage, but still they contained a very large quantity of organic matter. The quantity of nitrate was not at all high in those liquids. They were chemically precipitated followed by polarite filters which were not working very satisfactorily. One or two parts of chlorine per 100,000 was the quantity we used.

4395. (*Professor Ramsay.*) Is it possible to regulate the addition of chlorine so that it will not become a nuisance if the river is to be used for drinking afterwards?—Yes; we added the chlorine so that it should remain for ten minutes—so that an iodine reaction should remain for ten minutes; they could follow it down for ten minutes, and after that time the chlorine was used up by the organic matter, but this gave a sufficiently long contact to destroy the organisms in that time.

4396. (*Sir Richard Thorne.*) I suppose you will admit the effluents should be treated differently according as the water lower down the stream is to be used for drinking purposes or not, would you not?—Yes.

4397. You say yes in a very hesitating manner?—Yes, I say it hesitatingly.

4398. Why?—Because it is quite possible to make all effluents suitable for drinking purposes.

4399. Possibilities, yes; but we have to think of practicabilities?—That is why I said yes hesitatingly.

4400. Then I was coming to this. Would it be practicable, do you think, to draw the line as to making the effluent sterile in the case of streams, the water of which is lower down used for drinking purposes?—That is rather a big question; it depends so much on the stream. It would be a very great hardship, I think, to make all the sewage works above the London intake to deliver a sterile liquid. They have already spent a lot of money for the benefit of London; I do not know why they should be asked to do that additional work as well.

4401. Even near the water intakes you think it would be hard?—Yes; there are some very large towns near the intakes—places like Maidenhead and Reading, and so on.

4402. They are some distance above the intakes of the London water companies, and there, of course, you have a vast body of water as well?—Yes

4402*. Anyhow you do not care to express an opinion on that point?—No.

4403. (*Professor Foster.*) Do you remember whether there is any evidence that that chlorine destroyed the spores as well as the adult bacteria. Was that point gone into in your inquiries, do you remember?—Yes, it was gone into, and it destroyed some spores, but not all to the same extent. I think they got bacilli enteritidis sporogenes surviving even after moderate chlorine doses.

4404. (*Sir Richard Thorne.*) In one part of your evidence you say that the pathogenic qualities of an effluent are ignored by all existing standards, and then you go on to say that a very small amount of nitrogen or carbon if in the form of ptomaines would be sufficient to condemn an effluent; if drinking water be not in question, what harm do ptomaines do?—Well, that meant to apply to the possibilities of the liquid being drunk afterwards.

4405. Then you do draw a distinction between effluents that pass into streams that are to be drunk and those which are not?—Yes.

4406. My real point was to ascertain what significance you attach to a ptomaine apart from a pathogenic organism?—They are both undesirable things to go into a water supply that is going to be used for drinking purposes. Of course I should attach more importance to a pathogenic organism which was capable of surviving than to a small quantity of ptomaines which would be mixed with a large quantity of water afterwards.

4407 You probably know of no experiments as to the influence of small quantities of ptomaines passing into large quantities of water?—No, I should think they would have very little influence.

4408. (*Professor Ramsay.*) On fish, probably?—Yes, we were talking about the drinking supply lower down.

4409. (*Professor Foster.*) The poisonous qualities of ptomaines are not so intense?—No.

4410. (*Sir Richard Thorne.*) You speak of fish every now and then; do you attach the smallest possible value to a fish being able to live in an effluent?—I do not think it is a very good test; it is not an absolutely certain test certainly.

4411. Is it not notorious that you can have any number of fish living in a stream at the outfall effluent and find the banks of that stream below simply laden with sewage fungus?—I say here: "While an effluent which kills fish is obviously unhealthy, it does not follow that one where fish will live is therefore a good one. It is well known that fresh water fish are gross feeders, and fish in large numbers are often seen to congregate at the mouths of sewers where fæcal matter is visibly floating, being attracted by the fragments of foods and insects carried down by the sewage. Fish, in fact, are more affected by muddy water and by chemicals from factories than by excreta."

4412. (*Professor Ramsay.*) Would you not regard fish as simply a test for oxygen?—Yes.

4413. (*Sir Richard Thorne.*) It was the fact of your having quoted it twice that led me to ask you that. I have only one other question I think, and I am not at all sure that that part has not been already made clear by Professor Foster's inquiries. May I take it that you consider that the best method of dealing with sewage is after the removal of the coarser solid matters that the sewage should first be dealt with by anaërobic organisms?—I put it in this way, the coarser particles I believe are dealt with by the anaërobic process, but if you are going to remove the coarser particles first——

4414. Pardon me, when I said coarser particles I meant very large solids?—You generally have a screen to keep back very large solids—sewage solids.

4415. Ordinary sewage solids?—Paper and fæces.

4416. That the ordinary sewage solids should be dealt with anaërobically first, and then afterwards aërobically?—Yes.

4417. Then if that be so, does not the "resting full" of a filter diminish the number of the aërobic organisms?—Yes.

4418. And, on the other hand, the "resting empty" diminish the number of the anaërobic ones?—Yes.

4419. Well, does not that oscillation, so to speak, between "resting full," and "resting empty" go far to defeat the very object of the filter?—Yes.

4420. That is one of the points you wish to make?—Yes, and the analyses of such filters never give very high

nitrates. I have never found more than two, three, or four nitric nitrogen from such filters, and very frequently you find no nitrates at all from such filters.

4421. Then you would rather have a system in which the anaërobic work is always done separately under uniform conditions?—Yes.

4422. And the same again with regard to the aërobic?—Yes.

4423. You know Colonel Ducat's filter?—Yes.

4424. Where is the anaërobic work done there?—I do not know. I believe that the sewage there—a good deal of it—has already undergone anaërobic treatment in the sewers before it arrives at the filter, and that the anaërobic changes that take place must take place right at the top of the filter, in the centre and at the top of the filter, if there are any such changes taking place.

4425. I rather anticipated that answer. Well, now, if your view be correct as regards that, what becomes of the anaërobic process if it has not already taken place in the sewers, when you put sewage directly upon the land by broad irrigation?—You have then those lumps or masses of solids which can also undergo anaërobic treatment, because although they are in the air it does not follow that it will be an aërobic action taking place; they may be surrounded with a film of carbonic acid and an anaërobic change will be taking place in the centre.

4426. But that resolution of solids which is the main object of the anaërobic process is practically lost, is it not, in the land treatment?—Yes, and you get it remaining for a very long time on the surface of the land in broad irrigation.

4427. Is that one of the reasons why you consider these septic processes, as they are called, so superior to land treatment?—Yes, there is a very long delay before such solids disappear in broad irrigation. They would disappear quickly if they were buried beneath the surface.

4428. And if that process has to take place on the surface of the land, would there be risk to the stream on the occasion of heavy rainfall washing the material into it?—It washes it off the surface of the land into the stream untreated.

4429. (*Mr. Killick.*) I think that the whole of your evidence has been given on the assumption that the amount of purification in an effluent is sufficient to make it a drinking water?—Yes, I have tried to show how the best effluent can be obtained.

4430. Do you think that such a final effluent could be obtained from the sewage effluents in the manufacturing towns in the North and the Midlands?—It is a question of money.

4431. It is a question of money?—Yes.

4432. But if the question of money prevented such an effluent being turned out, you would want a different standard in that district from the standards which you adopt for drinking water?—Yes.

4433. Then it is possible that practically we come to this position, that the treatment of sewage for the purposes of purifying rivers, and the treatment of sewage for the purpose of turning it into a stream that is used for drinking purposes might be separated?—Yes; I think in cases like the Aire, where no one wants to drink the water, one could have a very different standard to that where it is absolutely necessary to drink the water below.

4434. At the present time I do not know if you know that there is no systematic dealing with the rivers in England except in the cases of the Thames, the Mersey, the Ribble, and the West Ridings Board?—Yes.

4435. So that the recommendation of standards to make effluents drinking water would probably arrest the work that is being done and prevent any further work being carried on?—Yes.

4436. You speak of using an amount of chlorine as a test, but that would be affected not only by the water supply of the town, but by the subsoil of the water of the town and by manufacturers' effluents?—Yes.

4437. Then probably it would be more unreliable than either the oxygen absorbed or the albuminoid ammonia?—Oh! I never attached any importance to chloride as a standard. Chloride as a standard would, I think, show first that the nitrogen should bear some relation to the chloride if that chloride has not been mixed with manufacturing refuse.

4438. (*Colonel Harding.*) You will appreciate how interesting it must be to this Commission to be guided as to the first process of artificial filtration, whether it should be aërobic or anaërobic?—Yes.

4439. You have expressed an opinion in favour of anaërobic treatment as a first process?—Yes.

4440. And I suppose I may take it from your answer to Professor Foster that that is in part due to your attention having been specially called to the Exeter septic tank experiments and to Mr. Scott-Moncrieff's?—Yes.

4441. And to your experience of the experiments at Leeds being simply at second-hand?—Yes.

4442. But assuming that the reports in regard to Sutton and in regard to Leeds are reliable?—Yes.

4443. I take it that you have no personal knowledge in regard to them?—No.

4444. It is evident that there is a considerable degradation or breaking down of solids in suspension by aërobic action in rough filters or rough beds?—Well, it is a question of words. There is undoubtedly an action, a disintegrating action, and improvement; the first filters, the coarse bed filters, do work; they destroy the organic matter, dissolve the organic matter, but to call it aërobic I am not quite prepared to agree with you. I have already said that the process is one which does not require air. There is no absorption of oxygen, and if the aërobes had been bringing about the change, they have been bringing about the change in spite of the air conditions, or in spite of the fact that they are aërobes.

4445. But do you assume that in the intermittent rough bacteria bed the action is to any extent anaërobic?—An anaërobic change inasmuch as it is not an oxidation which takes place in the first instance; it is a hydrolytic change.

4446. But is not the anaërobic action to be gauged to some extent by the result of the gases?—I will put it in this way: in order to get nitrate, in order to produce a nitrate, which is the final thing, you must get ammonia from your raw sewage. Now to get ammonia from raw sewage you do not require any oxygen, because there is no oxygen in ammonia, so that the first thing that must be done from a chemical consideration, apart from whether it is done by anaërobes or aërobes, is the production of ammonia.

4447. (*Professor Foster.*) But what is the evidence that ammonia cannot be produced save under anaërobic conditions?—Oh! I do not say that it cannot be produced except under anaërobic conditions. What I say is that the oxygen is not required to produce the ammonia.

4448. Yes, but that is not quite the point. I mean the point is whether the absence of oxygen is essential for the production of the antecedent phase of ammonia?—No, I have never said that it was essential, but I say that it is not required.

4449. (*Colonel Harding.*) I gathered that your objection to the intermittent rough filtration was that you had there opposing actions of aërobic and anaërobic organisms?—Yes.

4450. And that you thought it would be better to have a continuous action of anaërobic organisms than this oscillating action?—Yes.

4451. But how do you reach your conclusion that the action is aërobic and anaërobic; under such conditions does not anaërobic action bring about malodorous gases?—Yes.

4452. And may not the absence of such malodorous gases be taken to some extent as a rough test that anaërobic action is not taking place?—No; the gases are not very malodorous in small quantities, such as would be produced in such a filter. If ammonia is produced you can smell the ammonia in such a filter.

4453. Because the smell from a rough bacteria bed when it is dug down is not offensive; there is no putridity?—No.

4454. It is more of an earthy character?—A fresh septic tank liquid is not an unpleasant liquid.

4455. Always the gases arising from Mr. Cameron's septic tank are somewhat objectionable?—The gases, yes.

4456. Well, it is a very important point in deciding whether the first stage of bacterial treatment should be anaërobic or aërobic to consider whether the production of malodorous gases would really on a large scale be very objectionable. At Exeter you have an experiment on a

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small scale, but suppose you were treating the sewage of half a million people, would not the produce of methane really be very considerable and possibly cause a nuisance?

4457. It would be valuable, yes?—As a heating gas.

4458. But would there not be a somewhat serious element of danger in the very large production of methane under these circumstances?—Oh, no more danger than there is in a gas works.

4459. Quite so. That is to say that the tanks themselves would have to be very carefully constructed, with the view to preventing mixture of air and methane?—Yes.

4460. And if that were done on a very large scale it might involve a somewhat serious expense?—Yes, but it is a very valuable asset, I believe. With regard to the malodorous character of the gases even under anaërobic changes, I have frequently noticed in these upward filters, such as the Scott-Moncrieff upward filter, no smell at the top of them, so that there you have an obviously anaërobic change taking place, and yet the gas produced going through an upper layer of fluids has not been unpleasant at all to the nose.

4461. But surely those experiments are on a very small scale, are they not?—Caterham is on a population about the same size as Exeter.

4462. And you have not noticed any malodorous gases arising in that case?—No.

4463. Have you any experience of septic action in open tanks—uncovered?—No; but I have read descriptions of processes. I quite believe that septic action does take place in the open tank which is uncovered, provided the liquid is very still at the top, and covered over with a felt. There is a process in Church Accrington which is now being tried for which is claimed that it is anaërobic.

4464. Have you seen that experiment yourself?—No; I have not seen that.

4465. It is stated that they have been running an open septic tank there for forty weeks, and dealing with 1,000,000 gallons a day?—Yes, I can quite believe it.

4466. This question of the production of objectionable gases is, of course, rather a vital one in connection with your proposal to deal anaërobically in the first instance with sewage?—Yes.

4467. Now, passing on to the second process of filtration you have alluded to Mr. Scott-Moncrieff's series of trays, and I think alluded to them with approval?—Yes.

4468. As affording facilities for the classification of organisms?—Yes.

4469. But do you not think exactly the same results would take place under Colonel Ducat's?—Yes.

4470. So that really the only advantage of having a system of trays is a certain facility for obtaining samples at different depths?—Yes; the two filters are very similar. Yes, and the results should be similar. What has surprised me is that Colonel Ducat has not given in evidence the large nitrates which have been produced by his filter. I should have thought that they would have been produced.

4471. (*Professor Ramsay.*) We have found large quantities of nitrates?—I have been very much surprised at the figures he has shown me, and Dr. Houston's figures have only been such small nitrates—two and three parts per 100,000.

4472. (*Colonel Harding.*) Do you remember the figures of nitrates?—The only ones are Dr. Houston's, given me by Colonel Ducat, and the highest I think was about three of nitric nitrogen. With that Hendon sewage it would certainly go up to six or seven.

4473. (*Professor Foster.*) We have found from five to six?—That is what it ought to do. I am very glad to hear it.

4474. (*Colonel Harding.*) I should like to know whether you have formed any opinion as to the effect of temperature upon bacterial action. For instance, you are putting on a bed sewage at a temperature of 65 in summer; is the action distinctly more rapid than it would be in winter?—Yes; I think so. You find more nitrates produced in summer than in winter, and I believe the first change is more rapid also under warm conditions. The sewages recently that I have been having, containing large quantities of ammonia from Caterham with twenty of total nitrogen, have only come up to—the highest have been 10 to 11 of oxydised nitrogen. That is passing through these trays of Scott-Moncrieff's, give 11 out of 20, a little more than half the nitrogen, and that has been in frosty weather. I am in hopes that when the weather becomes warmer there will be more nitrification. One wanted, of course, the 20 of ammonia converted into 20 of nitric acid, but this 11 has only been obtained in winter time. Of course it may be that the size of these filters at Caterham are only sufficiently large for the number of organisms that can consume up to 11 of ammonia, and that he will have to increase the number of filters there, or the number of trays in order to get higher results, because that sewage has contained so much ammonia—20.

4475. Now in regard to the presence of organisms in the filtrate, the organisms in a filtrate may, in your opinion, be, as I think Sir Richard Thorne rather suggested, in certain cases valuable as possible evidence of probable further purification?—Yes.

4476. Are there no instances where, owing to certain chemicals being added for precipitation purposes, an antiseptic action arises which prevents the development of organisms in a filtrate, or in some cases absolutely does away with the presence of organisms in the filtrate?—That is so, I believe.

4477. In such cases it does not, of course, follow that because such a filtrate is free from organisms it is necessarily better; it may possibly be worse, may it not, than another effluent which does contain organisms?—Oh, yes, I think that was shown in that Manchester report, after the Manchester Rivers Committee of the Town Council visited those different works, and the work was done. It showed that many of those liquids which had been chemically precipitated failed to nitrify in the filters, and I fancy that that can be explained by the fact, as I mentioned before to Professor Foster, that the chemicals added actually sterilised that liquid, and as there was no nitrification in the filter, those liquids would be very bad liquids indeed, still containing the organic matter unchanged, except that which had been removed by precipitation.

4478. But for this reason I suppose that putrification would be arrested, and that on dilution it would proceed?—On dilution with river water you would have it all over again, and you would have a very bad state of affairs.

4479. (*Sir Richard Thorne.*) I think you understood my question as referring to rendering sterile the effluent, not the addition to anything before it went through a filter?—Yes, I usually talk about liquids from filters as filtrates. Of course, effluent may be a first process product or a final process product.

4480. Then I should like to say that my question had reference solely to a filtrate, and not to anything which was going to pass through a filter?—To a filtrate, yes.

4481. (*Colonel Harding.*) There is a small point, it may possibly not be of much importance, but in regard to the value of the physiological test of keeping fish in an effluent, you spoke to us in your first examination of the possibility of fish living near the mouth of sewers; but in that case would it not be largely because they can retire into the purer waters from time to time; that they endure the sewage conditions just as human beings do the bad atmosphere of a badly ventilated and crowded room for a while?—I think it is a question of the oxygen in the water. If the effluent is discharged into a river water which contains some free oxygen, the fish can live and go right up to that crude sewage. In your case, in the Leeds case, as the liquid is discharged it comes into contact with air afterwards; assuming that no change has been taking place it is aerated where the fish are living.

4482. But would you consider that quite a valueless test to see whether fish will live for weeks or months or years in the effluent; it is unmixed with river water of any kind?—I would not rely upon the fish living in my drinking water supply as the sole test.

4483. No; we are not speaking of the sole test, but is it not so far as it goes a useful test?—It simply shows that there is oxygen present in the liquid.

4484. That is valuable?—Yes.

4485. And it also shows that there are no elements antagonistic to life?—Yes.

4486. It is a sort of superficial test that if fish and vegetation can exist in such an effluent undiluted with river water it may be safely turned into the river?—Yes; that depends on the meaning of the term "safely."

4487. I am speaking of a stream which is not to be used for drinking purposes?—That kind of stream, yes.

4488. In your studies of the bacteriology of the subject have you come to any conclusion as to the possibility of

inoculating filters with any specific organisms which may be useful for nitrification or otherwise?—No, I do not think that seems to be possible; they would soon be contaminated with the organisms in the sewage, and it is very difficult to see how a pure cultivation could be obtained and maintain it; you can obtain a pure cultivation, but not easily maintain it.

4489. You would rather have conditions as in the trays of Mr. Scott-Moncrieff?—In a somewhat similar industry, the bateing of leather, the organisms have been isolated from dung, and the enzymes produced, and patents have been taken out by Messrs. Popp and Becker for the enzymes from sheep's dung, and these are being used for bateing leather in Germany. Of course, formerly, there, the bateing of the leather, which is a very similar thing to the liquefaction of the organic matter, has been done by the mob of organisms existing in the dung, or by the enzymes from that mob of organisms; now they are trying pure enzymes in order to hasten the process.

4490. And you think it would be a more promising way to try and bring about certain conditions than to actually inoculate with specific organisms?—I think it might be possible to produce the enzymes in large quantities in a separate tank, and introduce them into the first filter or the coarse filter gradually as the sewage came down so as to increase the rate at which the liquefaction takes place.

4491. (*Major-General Carey.*) Have you made any experiments yourself as to the effect of passing a large volume of storm water through bacterial filters?—I have been down at Exeter after very heavy storms, and I have noticed the change that takes place.

4492. Were they passing the whole of the storm water through the filters with the sewage?—No, I do not know that they have, but about double the normal volume was passed through the septic tank when I have been there.

4493. And the filters?—And consequently the filters. The filters have worked in two to three hours instead of five to six hours with very poor results. *Dr. S. Rideal.* 15 Feb. 1899.

4494. That is up to twice or three times the volume of the dry weather flow?—About twice the volume.

4495. Without any injury to the bacterial filters?—Without any permanent injury. Of course it is injurious from the point of view of that particular filtrate, because the results have been unsatisfactory.

4496. But the filters after the storm were able to deal with the normal flow?—Yes.

4497. As well as they did before?—Yes; and in the tank it takes some little time to right itself again, for the organisms to grow back, but in the upward filter, such as a Scott-Moncrieff filter, where the organisms are residing on the surface of flints or stones in the same way as they reside on the surface of coke on the filters, then the passage of storm water would have a less disturbing effect I take it than in the septic tank where there is no such surface.

4498. Would you consider it necessary to give the storm water and the sewage up to a certain volume, say, twice or three times the dry weather flow, the same period of rest as if the dry weather flow was treated separately: that is to say, supposing the twenty-four hours were divided into three cycles of eight hours each, allowing to the filter after being emptied, four hours rest, would you consider it advisable or necessary to give the sewage and storm water the same period of rest as if crude sewage alone was passed through those filters?—I think the period of rest should simply depend upon the volume and time of contact, not with regard to the absolute amount of work done by the liquid; that is to say, if you have a liquid which is twice the volume, that is to say, half as dilute unit volume would require the same time of rest in either case.

SEVENTEENTH DAY.

Thursday, 16*th February*, 1899.

PRESENT:

The Earl of IDDESLEIGH (*Chairman, presiding*).

Sir RICHARD THORNE THORNE, K.C.B., F.R.S.
Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary*.

Mr. BALDWIN LATHAM, called in; and Examined.

4499. You are a Civil Engineer, practising at Westminster, a Member of the Institution of Civil Engineers, Member of the Institution of Mechanical Engineers, Fellow of the Geological Society, Past President and Member of the Council of the Royal Meteorogical Society, Fellow of the Royal Statistical Society, Fellow and Member of the Council of the Sanitary Institute, and of other Societies?—Yes.

4500. You have been in practice for upwards of thirty-five years as a Sanitary and Waterworks Engineer, and have had very considerable experience in all matters relating to the disposal of sewage?—Yes.

4501. During that period you have had experience with various processes which have been brought out for the treatment and disposal of sewage?—Yes.

4502. You have constructed many works for the disposal of sewage in various parts of the country and abroad, both on the broad irrigation method, the intermittent filtration method, and various chemical methods, and combinations of chemical methods with land irrigation and filtration?—Yes.

4503. You have been engaged in various inquiries with reference to sewage disposal?—Yes.

4504. You have had the entire engineering charge of the inquiry carried out by the Royal Commission on Thames Sewage Discharge, in 1882 and 1883, acting for the Corporation of the City of London as the Port Sanitary Authority?—Yes.

4505. Can you give us any general sketch of your views on the sewage question?—There has always been considerable rivalry amongst the advocates of patent processes as distinguished from natural or land processes, and much of the want of success attending the purification in the past has been due to the advocacy of mere chemical processes as distinguished from natural processes for the purpose of purifying sewage. Sewage can be perfectly purified by its direct application to land, but it is desirable that where land treatment is followed, the solid matters in the sewage should not be passed on to the land with the liquid, otherwise it is found that such matter decomposing on the surface, is destructive to the crop, and is liable to be a nuisance, especially at certain seasons of the year. There is considerable difference in the qualities of lands which are suitable for the purposes of direct application of sewage. Porous gravelly subsoil with a fairly retentive soil on the surface is without doubt the most effectual for disposing of large quantities of sewage. On the other hand clay soils are those least adapted to the purification of sewage. Moreover, a clay soil has the great disadvantage, as pointed out many years ago, that if it is drained, the sewage passes direct into the drains without any purification. *Mr. B. Latham.* 16 Feb. 1899.

This was clearly exemplified in the case of the Norwood farm of the present Croydon Corporation, which was laid

Mr. B. Latham. 16 Feb. 1899.

out by me in 1853 and 1864. The land was found to be drained, and it was looked upon at that time as advantageous in the disposal of sewage, the land being a stiff clay, in fact London clay, with a very slight covering of clayey soil on the surface.

So soon as the sewage was applied to the surface of this land it went direct into the drains without any purification.

Subsequently alterations were made in the drains, and portions of the land were redrained with the idea of removing the drains as far as possible from the distributing carriers of the sewage, but after various alterations in the drainage, at whatever points the drains were located with reference to the distribution of the sewage, it was found that the sewage passed direct into the drains without purification, but ultimately the whole of the drains were removed from the land, and when that was done a pure effluent was secured, and the farm had been worked satisfactorily now for considerably over thirty years, producing a very pure effluent, which is turned into a very small water channel, in which, in the summer time, there is nothing but the sewage effluent flowing.

This ground, before its enlargement, has been able to dispose of the sewage of upwards of 300 people to the acre.

The effect of drainage on a clay soil is to dry it, and in drying in the least degree the soil shrinks, forming numerous free passages through which the sewage passes without purification.

The Croydon sewage farm at Beddington, a large portion of which was laid out under my direction, has a most favourable subsoil for the purpose of the disposal of sewage, being a porous gravel subsoil with a light surface soil. Such a soil as this might be drained with impunity, and would not pass crude sewage into the drains.

As a combined system for disposing of sewage by chemicals and land filtration, I would refer to the works which were carried out by me in 1882 and 1883 at High Wycombe, where a very small amount of chemicals was used, and the effluent passed on and through lands, there being no flow off the surface as in the case of the broad irrigation works at Norwood and Beddington. In this case the sewage of over 1,000 people to the acre has been most effectually purified on the lands which were originally laid out.

These are only a few types of works of the character which I have carried out.

Previous, however, to 1880 it was generally supposed that in the filtration and irrigation systems the crop on the land to a considerable extent aided the purification, and it was not until after the discovery of the nitrifying organisms in the Paris sewage farm that new light was thrown upon the whole question of the purification of sewage by land treatment.

Shortly after the discovery of these nitrifying organisms by Messrs. Schloesing and Muntz on the Paris sewage farm, the late M. Durand Clay, the Municipal Engineer of Paris, sent me an account of the discovery and the process by which it was discovered, namely, that the sewage was applied to a box of earth, forming a filter, and it was found by passing the sewage through it to be perfectly purified; but on the application of the vapours of chloroform to the soil, and the subsequent application of the sewage, it was found that the sewage passed through without purification, and by repeating these experiments the discovery was made of the living organisms in the soil which effected the purification.

It appeared also from the experiments which had been instituted by Sir John Bennett Laws, Sir Henry Gilbert, and Professor Warrington, at Sir John Bennett Laws' laboratory, that these nitrifying organisms were shown to occupy the surface only of the soils, which were dense like clay, but passed to a greater distance into the ground where the land was of a porous character.

In consequence of this discovery, in 1881 I determined to make experiments, and constructed some artificial filters while the works of the Croydon Rural Sanitary Authority were in progress at Merton, and which were in charge of Mr. Santo Crimp as my assistant, who subsequently made the bacteria beds which are in use at Barking

Directly afterwards I designed a series of filters at Friern Barnet with a view to the bacterial purification by filtration, and which were designed in 1883, and in 1885 they were carried out and came into operation in 1886.

These filters were constructed after the model of a filter in which the sewage was more or less passing continuously through them, that is, a system of controlled filtration was adopted.

The filters are 6 feet deep, and the bottom of them is burnt ballast to a depth of 2 feet 6 inches. On the top of this is a mixture of burnt ballast, breeze from the gasworks, and sandy soil, three feet deep, and over the whole surface of the filter a layer of fine sandy soil 6 inches in thickness is placed so as to control the rate of filtration through every part of the filter.

In a system of this kind it is essential that the sewage should be distributed over every part of the filter, so as to pass uniformly through each part.

A sample of the effluent from this filter was taken, without previous notice by a Deputation of the Corporation of Manchester on December 22nd, 1897, and the analysis of such samples gives the following results:—

FRIERN BARNET WORKS.

Description of Samples.

Crude Sewage, December 22nd, 3.20 p.m.—Considerable amount of brown suspended matter; sample taken shortly after stirring the sewage. Foetid smell.

Tank Effluent, December 22nd, 3.0 p.m.—Turbid, with grey suspended matter. Sewage smell.

Filtered Effluent, December 22nd, 3.15 p.m.—Bright and clear, no smell.

Analytical Numbers.

Oxygen absorbed, 4 hours:

	Grains per Gallon
Sewage (shaken)	6·23
" (settled)	5·28
Tank effluent	2·81
Filtered effluent	·30

Oxygen absorbed, 3 minutes (Incubator Test):—

	Grains per Gallon.		
	Before Incubator.	After Incubator.	Percentage Increase.
Sewage (settled)	2·17	5·56	150
Tank effluent	1·27	3·43	170
Filtered effluent	·096	·075	—

Remarks.—Both the sewage and tank effluent became very foul in the incubator. The filtered effluent remains perfectly sweet.

AMMONIA.

	Grains per Gallon
Free and Saline:	
Sewage (shaken)	5·30
" (settled)	5·40
Tank effluent	5·35
Filtered effluent	·025
Albuminoid:	
Sewage (shaken)	1·16
" (settled)	·82
Tank effluent	·56
Filtered effluent	·05
Chlorine:	
Sewage	11·0
Tank effluent	7·2
Filtered effluent	7·4

Remarks.—The sewage is of a domestic character. The tank effluent is of a highly putrescible character, containing a large proportion of albuminoids. The filtered effluent is of an excellent quality, showing signs of active nitrification, nitrites being present in it which are not shown in the tank effluent. The filtered effluent contained nitrogen as nitrates and nitrites, to the extent of ·55 grains per gallon. The disappearance of the free ammonia is noteworthy, being due probably to the layer of soil on the filter, such a layer being shown by laboratory experience to be capable of retaining and possibly oxidising the free ammonia. A portion of the soil from the filter was examined, and found to be capable of yielding considerable quantities of albuminoid nitrogen.

These Friern Barnet filters are about 1·44 acres in extent, and have been dealing with the sewage of between 6,000 and 7,000 persons per acre.

The sewage there is chemically treated, but the amount of chemicals used—sulphate of alumina and lime—is very small, and costs about one penny per head per annum on the population.

Experiments made on these filters show that very great care is required in working a filter, for an excess of chemicals will put the filter out of work.

It is also desirable that the sewage should be distributed over as large an area of the filter as possible. Since the removal of the distributing channels from the surface of the filter, there is a great liability for the sewage to pass unequally through only one part of the bed instead of uniformly through all portions of it.

If a filter is well aerated below, in a similar manner to waterworks filters, so as always to have the presence of fresh air in the filter, there is no reason why these filters should not go on working continuously, and most effectually purify the sewage which is passed through them.

The ordinary land filter would not pass and purify sewage at the rate at which the Friern Barnet filters pass it, and produce anything like the same results as to purification, as in land filters the nitrifying organisms really only occupy the upper portion of the filter, whereas if a porous filter is constructed, every portion becomes the abode of the nitrifying organisms.

In recent years I have also been making experiments with contact beds, as distinguished from filters, for the purpose of cultivating the nitrifying organisms effecting the purification of sewage.

I have designed and have at work for the Corporation of Manchester, a series of beds. I have also at Bilston, in Staffordshire, an experimental area, and also at Carshalton, in Surrey.

Charshalton is supposed to represent an urban district entirely water-closeted, Manchester a mixed population only partly water-closeted, taking the drainage from middensteads or ashpits, together with the refuse from chemical and dye works, and other manufactories. The Bilston sewage is highly charged with chemicals from the galvanising works, containing at times large quantities of salts of iron.

The process of contact beds, however, in all these cases, if properly worked, is found to be most effectual for the purification of the sewage, and, in fact, there appears to be no sewage that. with the aid of a small amount of chemicals and by passing a sufficient number of times through contact beds, could not be turned into water, absolutely as pure as that which originally supplied the district producing the sewage. For all practical purposes, however, the passage of the sewage through two contact beds will effect just as much purification as can be effected by the irrigation process on the best of lands.

The following are analyses of the effluents from Bilston and Carshalton, which give the results of the treatment by the contact beds :—

Laboratory, Plough Court,
37, Lombard Street, London, E.C.
24th January 1899.

R. H. Harland, F.I.C., F.C.S.,
Analytical and Consulting Chemist.
Public Analyst.

Reference Nos., C. 6,875/8.

Bilston Sewage.

Samples received from Baldwin Latham, Esq., on 7th January 1899.

(Taken 5th January 1899.)

Results in Grains per Gallon.

	Sewage.	Tank Effluent.	Effluent No. 1 Contact Chamber.	Effluent No. 2 Contact Chamber.
Total solid matter	82·6	72·1	69·3	69·3
Chlorine	19·38	17·15	16·15	15·65
Equal to Sodium Chloride (Salt).	31·9	28·2	26·6	25·8
Nitrogen as free Ammonia	·330	·329	·627	·560
„ Albuminoid Ammonia.	·060	·040	·048	·027
„ Nitrates	—	—	1·698	2·420
„ Nitrites	—	—	·175	·155
Oxygen absorbed in three minutes.	·504	·385	·140	·140
Oxygen absorbed in four hours.	·994	·798	·350	·287
After five days' incubation at 80° F.:				
Oxygen absorbed in three minutes.	—	—	·132	·126
Appearance after incubation.	—	—	Clear	Clear
Suspended matter:				
Organic	37·8	—	—	—
Inorganic	41·2	—	—	—

(Signed) *R. H. Harland.*

Reference Nos., C. 6,618/20.

24th December 1898.

Carshalton Sewage Ballast Tanks.

Sample received from B. Latham, Esq., 13th December 1898.

(Taken 12th December 1899.)

Results in Grains per Gallon.

	Crude Sewage entering First Tank.	Effluent from First Tank.	Effluent from Second Tank.
Total solid matter	48·3	61·6	63·0
Chlorine	3·5	4·2	4·2
Equal to Sodium Chloride (Salt).	5·76	6·92	6·92
Nitrogen as free Ammonia	1·288	·532	·1344
„ Albuminoid Ammonia.	·112	·0896	·0616
„ Nitrates	1·1760	1·7080	2·2176
„ Nitrites	nil.	nil.	nil.
Oxygen absorbed in three minutes.	·329	·294	·637
Oxygen absorbed in four hours.	1·001	1·120	1·285
After five days incubation at 80°F.:			
Oxygen absorbed in three minutes.	·455	·420	·175
Appearance after incubation.	Blackish growth.	Slightly cloudy.	Slightly cloudy.

(Signed) *R. H. Harland.*

Mr. B. Latham.

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At Manchester also I have tried what is known as the septic method, and passing the sewage through one bacteria bed ; but it is not found to be so perfect with the Manchester sewage as by simply passing it through two bacteria beds.

The following is a comparison of the results of the two methods :—

AVERAGE Results of Three Weeks' Trial.

	Raw Sewage.	Septic Tank Effluent.	Septic after Filtering.	Raw Sewage.	First Rough Bacteria Bed.	Second Bacteria Bed.
Oxygen absorbed in four hours.	4·99	4·98	1·85	5·40	2·68	0·95
Free and Saline Ammonia.	1·60	1·15	0·68	1·36	1·00	0·57
Albuminoid Ammonia.	0·24	0·15	0·072	0·24	0·12	0·06
Chlorine	10·7	9·77	9·78	10·62	10·27	9·90
Ammonia from Nitrates and Nitrites	—	—	·313	·153	0·0:0	0·248
INCUBATOR TEST :						
Three minutes' oxygen absorption before incubation.	3·05	3·15	1·18	3·13	1·69	0·52
After incubation	—	3·52	0·97	3·56	1·85	0·43

That with bacteria beds three feet deep, there can be little doubt that the sewage of 10,000 people per acre can be perfectly purified. This system, however, will require more constant attention than the controlled filtration through bacteria beds, as from experiments I have made, I find it is essential that the bed should fill quickly, so as to retain the air within the porous material. If the bed is filled very slowly indeed, an anaërobic organism develops instead of the aërobic.

It is essential also that after having been in contact, the bed should be effectually drained and allowed time for aëration.

The construction of the beds is also an important point. Hitherto, in most of the beds that have been constructed, the drains have been laid upon the floor of the bed, and the consequence is that owing to the porosity of the material, the sewage passes at once into the drain, and fills it with unpurified sewage, so that the first waters draining from the beds are impure by reason of the discharge of a mixture of sewage and purified effluent.

This difficulty has been got over by a method of construction, in which the drains serve the purpose of draining the beds completely, but when the beds are emptied, the drain itself is left full of purified effluent.

It is also essential that beds of this character should be as near as possible of a uniform composition throughout, and not made, as they have been, of coarser material at the bottom and finer at the top, like a controlled filter.

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There are not many places in which a sufficient fall could be commanded so as to work two sets of bacteria beds one after the other, and in order to be able to command the double beds, it might be necessary in some cases to pump the sewage.

In this case, of course, it would be desirable to know which would be more economical, to apply the sewage direct to land, or to the beds in question; but in all cases where there is a difficulty in acquiring land, or the lands are not suitable for the purposes of irrigation or land filtration, the bacteria bed system offers a complete solution for the purification of sewage. Of course, in some cases it will require to be aided by chemical treatment.

4506. (*Chairman.*) I should just like to ask you a question or two about storm water; you have no doubt paid attention to the question of storm water?—Yes.

4507. Are you of opinion that the storm water should be allowed to go through the filters or that it should be diverted from them?—The question of storm water is an exceedingly difficult one to deal with. There is a great liability to enormous fluctuation in time of storm. I have made numerous experiments for many years with regard to how storm waters do affect sewers, and it is nothing uncommon to get a flow increase often thirteen times the average flow, for a short time; but it very rarely happens that that high rate exceeds one hour, but when the storm water does come down at these heavy rates it is extremely dilute, and in many cases of course we are permitted to send a very dilute water like that direct to the channels. I understand the Mersey and Irwell standard admits a proportion of six to one. When there is diluted sewage the storm overflows of Manchester might come into operation and so discharge the water direct into the Mersey and Irwell.

4508. Do you think that if it is allowed to pass through the filters it does them any harm by washing away the bacteria?—No. In the case of Manchester we have been considering that question, and what we do is, we get the whole of the diluted sewage through, but give it less time in contact with the bed.

4509. But do you not find it hurts the filter?—It does not necessarily do so, because the effluent from a single bed is often weaker than dilute sewage in time of storm. As I say, the sewage itself complies with the standard before treatment, and instead of having a double bacteria process at that time we propose to carry out a single process and limit the time, so that we should be able to deal with many volumes larger than we ordinarily deal with.

4510. You mean you would only pass it through one filter instead of two?—Pass it through one filter instead of two, and then have a shorter time according to the condition. What is proposed to be done in every instance is to determine by the three minutes' oxygen test what is the strength of the sewage, which can be done on the spot with a careful chemist, and know exactly how you have got to deal with the sewage—in which way, and if a sewage is shown by the three minutes' oxygen test only to require a limited treatment, then we should only give it a limited treatment.

4511. Then you do not find it does any harm to the filter beds?—No, none whatever.

4512. Turning to the question of the land treatment of sewage, do you think that when the land is frozen any purification of sewage takes place?—I have never found any difficulty with regard to it. As a rule, at the periods of the year when we have severe frosts the sewage is always warmer relatively than at other periods, and what often happens is that a film of ice is formed a short distance above the surface of the land—if it is a growing crop like grass, a few inches—above the surface, and the sewage flows on to the land underneath it. We have never had any difficulty in my experience.

4513. And the purification goes on taking place?—Just the same. But I should say this, this was a matter also which for some years I dealt with, because it was thought—in one of the Commissions' report—that in time of frost it would not do so, but what I found was this, that in time of intense frost a portion of the sewage was frozen, and all that which was frozen was pure water; that is, when water freezes it is only the pure water that freezes, not the sewage, and the consequence was that a very large quantity of pure water was locked up, and the effluent at that time was very much smaller in proportion to the volume of the sewage but the moment the thaw came we got a most unprecedented degree of purity, because of the dissolving of this ice which had been locked up producing an artificial purity by dilution, so that I think very much of those ideas which were formed a few years ago were due to the fact that the subject was not fully investigated. It was not due to any inaction of the land, but simply due to the fact that the effluent itself represented very many more volumes of sewage at times of frost than it did at any other periods.

4514. Then, in fact, you think the purification goes on in very cold weather and throughout the English winter?—Oh; indeed, it does; there is not a shadow of doubt about it. Take the farms at Norwood, the clay farm, or the Croydon farm, there has never been the slightest difficulty in cold weather; in fact, our greatest difficulty is in very hot weather, when a certain colouring is given to the effluent due to the heat of the water dissolving certain organic constituents.

4515. I suppose you would agree with what is generally said now, that it is impossible to lay down any hard and fast rule as to any particular area of land being required for any particular population?—That is so.

4516. It must depend upon the quality of the land?—It must very much depend upon the quality of the land itself.

4517. Do you think any purification of the sewage possible where the land is water-logged?—Well, it depends upon what water-logging means, because every field when it is put under sewage is waterlogged for the time being, and some years ago I made some experiments upon that point, because when this question about applying sewage to land was fought, the opponents to it said, "Oh, look, in time of rain when the land is waterlogged why you will get no purification; you cannot get the sewage into the land." I had a glass tank made and filled with very fine sand, and charged this with a solution of iron salts, and put it on a gentle incline to ascertain what the movement of water was in the soil itself, and by putting on an infusion of nut galls it formed its own diagrams from day to day as the water ran through this long tank, and then it was shown that the most feeble currents displaced the water which was in the soil and took its place. That is exactly what happened in rainy weather at a sewage farm. We always got the best effluent possible in rainy weather instead of the worst, simply because one increment of sewage put on a field displaced the water already there, and took its place, so that the great fear of water logging of that description is no detriment to it. But of course I quite understand that if land is permanently under water it would not be desirable to go and put more water on it.

4518. Have you ever known of the soil of an old sewage farm being analysed bacteriologically?—No, I have never had occasion myself to have anything of that kind done.

4519. I mean you never heard of a case?—No, I have not.

4520. In your evidence I think you have told us that the effluents of sewage that passed through two of your contact filters is as good as the best effluent that you have ever had from any land treatment?—Yes, that is so.

4521. And that you feel confident about?—That I feel confident about, because when tested with the very worst sewage that we have got to deal with we get these good results. I have got three sets now in three different towns of these bacterial beds experimentally working, namely, at Carshalton, here, and at Bilston, where we have to deal with a strong chemical effluent highly charged with salts of iron from the galvanising works with a very large quantity of chlorine as it will be seen which principally arises from those works, yet we do find in that case that better results are produced if a little lime is added to neutralise the acidity of the sewage before it is applied to the beds, but I do not know any case in which as good a result is not got, and probably better, than by the application to land. The same treatment would have to apply chemically if Bilston sewage was put on to land. If we put that iron liquor upon land, why, it would kill everything upon the land, and it would be necessary exactly just to have the same treatment as if it were put on to a bacterial bed.

4522. As to the pathogenic organisms, do you imagine that they would stand as bad a chance of getting through your contact bed as they would in getting through a sewage farm?—I do not think so. I could not answer that for certain, but we know on a sewage farm the experience shows—for instance, I remember in 1875 there was an epidemic of typhoid at Croydon, when there was some-

thing like over 1,200 cases in the town, the sewage was applied to the sewage farm, and all the houses in the neighbourhood at that time took the water supply from local wells in the neighbourhood, and the water in these wells used to rise and fall with the proximity of irrigation to them, but in that year and subsequently there never was a single case of typhoid in the neighbourhood of the Croydon sewage farm.

4523. Do you mean that you think pathogenic organisms could not get through a sewage farm?—I think so. It is quite clear from my experience that they could not be passed through.

4524. They could not get through?—I am certain of it.

4525. And do you think they could not pass through your artificial beds?—Well, I think the conditions are such that the exposure that sewage would get in a bacterial bed in contact with probably these friendly microbes in the bed would probably lead to their destruction. That is the only conclusion I could come to. I know there is a doubtful case at High Wycombe, where it is supposed that an epidemic of typhoid arose in connection with that sewage work, but I have very great doubt indeed whether it did myself. I know the work. I originally laid it down; but it was due probably to the local pollution and to an alteration of the subsoil water due to bringing a mill into work which had not been at work for some time, for nothing of the kind had occurred before until this particular time that this mill came into operation, but I mention it because there has been a report upon it.

4526. Would you, on the whole, be prepared to say that you thought artificial filtration as safe as land treatment?—I will not call it filtration; it is really not filtration. I think it is quite as safe myself. I do not see any reason why it should not be seeing the results of the analyses that the effluent is quite equal to that of any from any sewage farm, but as a rule, of course, effluents of this kind are never used afterwards for the purposes of water supply unless they have been passing through long distances of flow of water, and that very exposure afterwards, no doubt, would render them as wholesome as it would an effluent from a sewage farm.

4527. (*Mr. Killick.*) Would you kindly explain why you use the expression "contact bed" in preference to "filter"?—Because it is not filtration in any sense of the word. Filtering is a straining process which takes place from the surface downwards. The contact beds fill up from the bottom upwards, and simply lie in contact; there is no straining and no removing in that sense as filtering.

4528. I understand that you propose in Manchester to deal with the sewage on two contact beds, or more or less, according to the quality of the sewage?—Yes, that is so.

4529. And therefore in that way to some extent you meet the difficulty of storm water?—Yes.

4530. Do you know the figures of the increased Manchester flow during the recent wet weather?—Well, it has not been very great there, numbers of storm water overflows come into operation which discharge the excess of water into the streams before it comes to the sewage works. There are no figures showing more than double the quantity of the dry weather sewage that I have been supplied with as coming down to the outfall.

4531. As regards the storm overflow, you speak of a limit of the Mersey and Irwell Committee; would you kindly explain?—Well, there has been an agreement entered into between them and the Corporation of Manchester that the storm overflows may come into operation after a certain dilution locally.

4532. An agreement?—An agreement.

4533. Perhaps you had better say understanding?—Well, it is really set out in black and white.

4534. I do not think you can quote the Mersey and Irwell Joint Committee as having laid down a standard in this matter?—Well, they have a standard for sewage also.

4535. We are speaking on a question of storm overflows?—There is an agreement to that effect.

4536. An understanding?—That is another name for the same thing.

4537. It is rather important, my lord, because this, in all probability, may be quoted against us. (*To witness.*) I should like to call your attention to what I think, perhaps, are misprints in your statements. On page 11 the quantity of albuminoid ammonia in the sewage is put at ·060; is that right?—Yes.

4538. Is it not ·60?—No, I do not know; I think not. I think there is a large amount of iron salts in that.

4539. Over the page oxygen absorbed in four hours, the sewage ·994?—Yes.

4540. It is very weak sewage then?—It is probably a weak sewage containing—being precipitated with this large quantity of iron salts in it, really water comes down there perfectly brown in colour—the sewage.

4541. At the bottom of that page oxygen absorbed the crude sewage, Carshalton sewage, crude sewage, first tank 1·001; is that right, because the final effluent is 1·285?—I could not say without reference to the actual analysis; I will look at it.

4542. It is apparently an error?—Yes, I should think so.

4543-4. Then Manchester average results of three weeks' trial, albuminoid ammonia, raw sewage 0·24, first rough bacteria bed 0·14, second bacteria bed 0·60. That surely is wrong?—I should say so.

(*Colonel Harding.*) It is intended for ·06, I suppose?

4545. (*Mr. Killick.*) I think so; perhaps Mr. Baldwin Latham will examine these figures?—I have not seen this typewritten copy.

4546. Albuminoid ammonia?—I have not got that one; it is ·06, there is no doubt it is; I have got that.

4547. There is a sentence here which I do not quite follow in the paragraph after these tables for Manchester: "This system, however, will require more constant attention than the controlled filtration through bacteria beds, as from experiments I have made I find it is essential that the bed should fill quickly so as to retain the air within the porous material"?—Yes.

4548. This system refers to the contact beds?—To the contact beds. I have found that if a contact bed is very slowly filled indeed, that the anaërobic organisms are developed and you get putrefaction. That it is essential that sewage should be put on as quickly as possible so as to retain within the material itself as much air as possible, so for a long time after it is put on you will find the air bubbling up to the surface; but when it is very slowly filled you do not get that air retained.

4549. The distinction is between a contact bed and a controlled bed?—A controlled filter means downward filtration with a fine layer on the top, which controls the rate at which the liquid flows over the materials below.

4550. In the last paragraph, the last sentence, you say, "In some cases it will require to be aided by chemical treatment." Can you give some instances of those cases?—Yes, I was mentioning one this morning, Bilston, where you have got an enormous quantity of iron salts coming down. I know that from the working of the Friern Barnet filters, which have been working for over twelve years, that those could readily be put out of work by an extra dose of chemicals being put on to them at any time, and, therefore, if a sewage contains a very large obnoxious chemical, it is necessary that it should be qualified; for instance, these acid salts of iron, such as you have got at Bilston, as you see from the analyses of that particular sewage here, containing, as it does, so much chlorine which really was in combination with hydrochloric acid, that an effluent of that kind put on the filter would probably, for the time being, destroy the action of the organisms, as was shown in an actual experiment at Friern Barnet, by putting on an extra dose of the chemicals we could pass the sewage without any purification through one of these controlled filters.

4551. You would suggest that in the case of the treatment of a sewage such as you propose in Manchester by two contact beds, the sewage itself should be constantly watched and analysed, and under certain circumstances should be turned into precipitation tanks with chemicals before being put on to the land?—Yes. Well, what we propose to do at Manchester is to pass the sewage through the existing tanks, which hold a half day's supply, so that we can get a more mixed quality of sewage, because the sewage itself is naturally alkaline, and if we could get a sufficiency of mixture it would not be necessary to use the chemicals at all; but in small towns and in places where you are constantly dealing with large quantities of chemicals it is absolutely necessary that some chemicals should be used, especially lime, which has been found to be most effectual.

4552. (*Colonel Harding.*) I see that your experience enables you to express a strong opinion as to the possibility of good results being obtained by passing sewage through contact beds. You think that if it was passed through a sufficient number that you could actually restore the original purity of the water which supplied the district?—There is not the shadow of a doubt about it.

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4553. And you think two contact beds will effect as much purification as could be effected by the irrigation process basis on land?—That is so. You understand with an irrigation process we find it is often necessary to pass the sewage two or three times. In irrigation works in which the sewage is only passed once over the surface of the land it is not usually satisfactory. For instance, take a large farm like Beddington, where you have surface irrigation, it is always the practice to send that water at least twice over the surface of the land; send it over one field, pick it up, and send it again over it.

4554. I find that this opinion refers specially to contact beds and not to continuous controlled filtration, such as you have had, for instance, going for a long time at Friern Barnet; have you views in regard to that?—Well, the same thing would apply to that. I can conceive circumstances in which a controlled filter may be put out of work, as I know, for instance, at Friern Barnet they have removed the distributing channels from off the surface, and secondly when they dig over or harrow over these filters there is great liability of the sewage first of all going through at one place near the inlet. Well, that is not controlled filtration.

4555. Then at Friern Barnet the effect of the top layer of sand is really to secure even distribution?—Even distribution that is all the effect of it.

4556. Obviously in that case you must be dealing with sewage which has been thoroughly precipitated?—That is so.

4557. If not the sand would very soon have a coat of sludge which would require constant removal?—We use a small quantity of chemicals always at Friern Barnet, but the chemicals are very small, and the value of them comes to exactly a penny per head of the population per annum.

4558. Do you happen to know what solids in suspension there are in the effluent flowing on to the Friern Barnet filter?—I think I can supply that.

4559. Would there be one, two, or three grains per gallon?—Oh! very little, indeed, not more than one grain per gallon.

4560. Has there, as matter of fact, been any accumulation on the upper surface of the sand?—After these filters have been at work for some time it is customary to harrow them over; not a particle of material has been taken from the surface of the filters when they are dry. They are used alternately. There are four of them, but when the filters are dry they are harrowed over with light harrows drawn by a couple of men.

4561. Nothing has been removed?—Nothing has been removed during the whole period the filters have been at work.

4562. In a case like that where the upper surface is hermetically sealed by a layer of sand covered with liquid sewage, do you find that you are able effectively to aerate the lower portions?—Well, the filters, as a rule, are always aerated from below like a water filter, but the channel is brought up by the sides above the water line to admit air almost at all times, so that the drains are all open until surcharged, so there is an excellent circulation of air in the filters.

4563. I suppose your preference for contact beds is partly for this reason that you are able there to deal to some extent with solids in suspension?—Yes; we can deal with solids in suspension, and we virtually in Manchester have been dealing with crude sewage. We have put the crude sewage on to the beds without any subsidence even; we have made experiments with subsidence and without.

4564. Then let us come, please, to the Manchester sewage experiments that you have been carrying on. What is the size of the two contact beds that you have there been working with—quite roughly?—I could not say exactly now.

4565. 20 by 20 feet or yards?—About 17·5 feet by 17·5 feet at the bottom.

4566. 35 by 25?—Something like that; and at top they are 29·5 by 29·5 feet.

4567. 30 by 30 feet?—Yes, and 3 feet deep.

4568. Tell me, when were they started?—Oh, some months ago now. It was last September when they ordered them to be made.

4569. You refer to three weeks comparative experiments with the septic tanks, and with the contact beds at Manchester?—Yes.

4570. How long had the septic tank been working, and how long had the contact beds been working?—The septic tank had been working a very much shorter time, as it took a very long time to bring them into operation.

4571. That is what I wanted to reach. When you made these comparative tests, had the septic tank and the contact beds reached their full working conditions?—Well, I do not know that they have now, because there seems to be a gradual improvement going on in these beds.

4572. In both?—In both of these, but much more so in the contact beds than in the others.

4573. Then the final results do not appear to vary very much after the sewage passes through the septic tank and filter, and the sewage passes through the double bacteria beds, it produces results which are not very dissimilar?—Except in the oxygen test.

4574. We will take the oxygen test?—The oxygen test would not comply with the Mersey and Irwell standard.

4575. In the case of the albuminoid ammonia test the results are substantially alike?—Yes, that is so.

4576. And you, yourself, suggest that the septic tank may not have been at the time in working order?—Oh, it was in working order, but we did not take any samples at all till the whole thing was in working order.

4577. How long were you working?—They started the works at the same time as the double filters were started to make them, but they did not come into operation for some months afterwards.

4578. When the Commission visited Manchester, were not the septic tanks in course of erection?—Yes.

4579. Therefore the septic tanks were not working so long as the contact beds?—That is so.

4580. Therefore it may be assumed that the one might be in better working condition than the other. Are you able to express any opinion upon that?—I should say the septic tank had got to its proper footing before we made any experiments for the purpose of comparing.

4581. Do you think that the experiments at Manchester have been carried on sufficiently long, and have been watched with sufficient thoroughness to enable you to say that the one system at Manchester is preferable to the other?—I should say at Manchester certainly so, but I should not say so generally, because I have very great faith in the septic tank for ordinary sewage.

4582. Then was the sewage which was passed through these septic tanks, and that which was passed through these contact beds exactly the same?—Exactly the same, and taken on the same dates.

4583. Be good enough to tell us what its condition was; I understood you to say that it was partially settled sewage?—No, sir; crude sewage.

4584. Absolutely crude sewage?—Yes. Crude sewage passed on to our beds, this three weeks test; absolutely crude sewage every day.

4585. Nothing whatever had been precipitated?—Nothing whatever had been precipitated.

4586. Then have you any data at hand to enable you to tell us what was the amount of solids in suspension as the sewage went on to your filters?—I do not know; I have got all the detailed analysis here.

4587. This is rather material, because I notice in your evidence you do not tell us anything as to the sludging up of these beds, as to how far solid matter put upon the beds is broken down, or how far some of it is left behind to accumulate, and one would like to know, therefore, exactly what was the condition of the sewage as it went on, how many grains of solids per gallon there were?—It does not give it in either case the actual amount of suspended matter.

4588. Have you nothing to show what that is for Manchester sewage generally; would it be something like forty grains per gallon?—In no case is it given.

4589. Then you have no data either of the amount of solids in the filtrate from the coarse bed—solids in suspension?—The solids in suspension? Well, I have got some data with reference to that, but they are not here.

4590. What I want to get at is as to how many grains per gallon are retained in the rough bed, and how many to the fine bed?—Well, the effluent is practically free from suspended matter when it comes off the rough bed.

4591. Is that really so?—Yes, practically; that is, it could have a very small quantity indeed—it is opalescent in colour.

4592. Do you suggest that almost all the solids in suspension are retained by the rough bed?—No, no; because I am afraid that by putting solid matter on to these beds, in course of time the finer matters will wash out on to the second bed; but that suspended matter will be ultimately washed out.

4593. Some of it?—Yes.

4594. But do you see any objection to that?—Well, there would be an objection to pass it into the Ship Canal; it would help to silt up the canal.

4595. No; but we are not understanding each other. You say some of the suspended matter might be washed out of the rough into the finer bed?—Yes, and out of the finer bed; that is, the sandy matter, but no organic matter. About half of the solid matter in the sewage is really mineral matter, which may cause a deposit.

4596. Do you think that would pass through not only the first, but also the second bed?—I have reason to believe that it will from my experiments.

4597. You have noticed gritty matter in the fine effluent?—Yes, I have where crude sewage has been put on.

4598. What experiments have you made at Manchester to ascertain the reductions of capacity of these contact beds?—These have been made by Mr. Fowler, the chemist, and it has been found to go on to a certain extent and then stop entirely, which clearly indicates that some of the solid matters must have been washed out again. I should say this with regard to this silting up of these beds: It is not such a serious matter, because the matter which silts up is fine sandy matter, which only limits the capacity of the filter, and makes it work slower—it does not actually stop the thing altogether. You would only require a larger area of filters to still carry on the process. The materials themselves are just as porous; they are capable of passing liquid through them.

4599. This is really a very important matter. Am I right in understanding you to say that Mr. Fowler finds that the capacity is reduced to a certain point, and then remains constant?—Yes, that is so.

4600. How long had the beds been working—four months?—Twelve months.

4601. You mean the recent filters?—The recent filters.

4602. But they are not dealing with crude sewage, but sewage filtrate?—At times a good deal of suspended matter comes down in time of storm, over the whole flow of the tank, and they found that the capacity of the filter has diminished to a certain extent, and then increases, and that the filter itself has risen up in the centre, so as to increase its capacity visibly.

4603. But Sir Henry Roscoe himself gave evidence before us that the average solids in suspension in what went on to these recent filters did not exceed more than 1½ grains per gallon. Now you are putting upon the contact beds, upon which you have been experimenting, the whole of the solids of the sewage of Manchester?—Yes.

4604. And it does seem to me a most material point to ascertain how long this test will go on without silting up?—Well, the beds have, to a certain extent, silted up. I have not the figures here, but I have got them measured, and I have got the means of measuring them regularly—the capacity of them.

4605. You are unable to give the Commission any information as to what the reduction has been?—I think it was something like 47 per cent.; they diminished to 36 per cent.

4606. 36 per cent. of what?—Of the actual capacity.

4607. Of the original water capacity?—Yes.

4608. That was in four months?—Yes, but we always reckon that a filter in efficient work should allow a capacity of 33 per cent.

4609. (*Major-General Carey.*) 33 per cent. of the water capacity?—Of its capacity; cubic capacity.

4610. (*Colonel Harding.*) Of its water capacity?—Of its cubic capacity; 33 per cent. is its water capacity of its actual cubic capacity.

4611. I am afraid that is not quite clear?—Suppose you have a filter of a cube yard.

4612. We are not speaking of the cubic contents of the bed before the material is placed in it; when the material, coke, breeze, or whatever it may be, is placed in it, obviously the capacity for water is greatly reduced?—Yes.

4613. We start from that, and call that the original water capacity, the first time the bed is filled; now what reduction has there been from that original water capacity to the present capacity?—Well, there has been a reduction, as I say; I think it is from 40 per cent. to 36 per cent., but that, in a great measure, is due to the materials flowing together. That is a settling due to the working and the action of water, but we ultimately anticipate that it will be reduced to 33 per cent. when that filter becomes perfectly efficient.

4614. (*Major-General Carey.*) 33 per cent. of the water capacity?—Of its full total capacity. Suppose it was a cubic yard; 33 per cent. is one-third of that.

4615. It is reduced from the start by 33 per cent. to get the water capacity?—33 per cent. is the actual water capacity.

4616. The moment the filter is full the contents are reduced to 33 per cent. to obtain the water capacity?—Yes.

4617. The water capacity will be 33 per cent. of the cubic capacity—of the actual capacity; 33 per cent. of the cubic capacity is the water capacity?—Yes, and 66 per cent. is of the material.

4618. (*Colonel Harding.*) You start then, when the bed begins its work with 33 per cent.?—33 per cent. is what you anticipate it will be.

4619. But you started with 36?—We started with something about 40 originally, but they settle down, the filters; they hold more to begin with.

4620. But you started at 40?—It may be 40—it may be a little more.

4621. What is it now?—It was 36 when it was last measured.

4622. Do you actually suggest that the capacity has been reduced in four months by only just 4 per cent.?—That was so.

4623. May I ask if you have seen the report in connection with certain experiments at Leeds?—No, I have not.

4624. Because the experience there has been that there is a very large reduction of capacity?—Well, the reduction of capacity in great measure is due to the filtering materials flowing together.

4625. What effect would that have?—Running together, consolidating.

4626. Would that reduce the capacity?—That would reduce the capacity, because the filter subsides when the water is put upon it, and often we have got to put fresh material on the top to make it up to its original level.

4627. Then is there not this, that if the material breaks up, by capillary attraction it retains a great deal of the water, and the filter does not empty?—That was so, because originally, when the filter was absolutely dry, it took much more than that, because we measured it on the dry material to begin with, but I have not got the figures here. I could give them to you, as well as the capacity from time to time since. We have measured them.

4628. Well, I suggest to you that that is a very important point for investigation in connection with Manchester experiments to get accurate results as to reducing the capacity of the filters?—Well, what we propose to do ultimately, when the sewage has all passed through a process of sedimentation, is this: there will be practically little or no solids to go on to these beds. We are only trying that out first to see what we do with them.

4629. Is it the intention of Manchester first to precipitate?—No, not to precipitate, but to turn the whole of the sewage through the tanks, so that the whole of the mineral matters brought down by the sewers shall be removed.

4630. That would be precipitation so far as the mineral matters are concerned?—Precipitation without chemicals.

4631. Only sedimentation?—Only sedimentation.

4632. How much would you remove?—We should remove one-half of the total sludge we have got to deal with.

4633. Your experiments of that nature have not yet been tried?—Oh! yes, they have. I have made experiments in the early period of sedimentation, and then those

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were so successful and answered so well that we thought we would try the crude sewage.

4634. Then you have not tried any experiments beyond those at Friern Barnet in continuous filtration combined with continuous aeration?—Yes; I have got a small bed working at Carshalton, and I have got a large area which will shortly be at work there of the same description.

4635. Could you tell us exactly in what way that is being done?—The sewage at Carshalton will be treated chemically and then passed on to these artificial filters.

4636. Additionally?—Additionally.

4637. And in that case do you use the system of sand distribution?—Yes. It is not sand; it is a sandy soil; six inches of sandy soil is put on the top of the filter; the filter itself is composed of breeze and burnt ballast, and a little sandy soil mixed with it.

4638. Now, from an engineering point of view, the relative value of the septic arrangement which you have been experimenting with at Manchester, and the double contact beds would offer these distinctions, would they not, that in the case of the septic arrangement you could work more on one level; in the case of double contact beds you must necessarily have the first raised above the second?—Yes, that is so.

4639. And therefore possibly pumping arrangements would be involved in the second case which would not be necessary in the first?—That is so, but then you see a sudden flow of storm water through a septic tank would be much more deleterious to us than it would be through two filters.

4640. You think it would wash out the septic tank, and would not wash out the filters?—Certainly. Then I have also to take into consideration the expense; the expense of making a large area of covered septic tanks would probably be double that of a corresponding area of filters to deal with the same quantity.

4641. Have you formed any opinion as to the necessity of covering septic tanks at all?—No; my impression is from what I have seen that we get rid of a very large quantity of matter indeed in an open tank if you only give it time to pass through.

4642. But you think there might possibly be objections to cesspools?—Yes. Tanks, if they are left open for any length of time, decomposition takes place and a layer perhaps a foot deep of frothy offensive matter accumulates on the surface of them. I have seen in the case of the Burton tanks when they were formerly at work, a layer there that the sewage used to ferment from the character of the sewage itself, from the washing of the beer barrels going into it, it used to ferment, and you would get a sort of barm on the top of the filters over two feet deep.

4643. Which in a way acted as a roof?—Of course, but still it was very disagreeable, the smell coming off this decomposition going on.

4644. Just one more question: do you happen to know whether these analyses which you have given to us in regard to Manchester, Bilston, and Carshalton, are analyses of sewage and effluents which have been settled or filtered first before they were analysed?—Well, the crude sewage is taken from the sewers direct in the case of Bilston.

4645. But did the chemist who made these analyses allow the samples to settle first and merely analyse the supernatant part, or were they shaken up; do you happen to know?—I cannot say; I could ascertain, but Mr. Fowler himself, no doubt, if you have him, could tell you definitely in regard to these samples. Every sample is very fairly drawn. The Corporation of Manchester have spared no trouble or expense to see that this thing was effectively and properly carried out.

4646. (*Mr. Cotton.*) With regard to the Norwood farm, how was that drained originally?—It was drained originally as an ordinary land drainage.

4647. How deep?—About two feet six inches—three feet deep, probably three feet.

4648. And the result was that the ground broke up by cracks and became useless as a filter?—The result was you would not observe any cracks upon it, but minute air openings occur in all clay soils when it is drained, and through these air cracks the sewage went direct to the drain without purification.

4649. However, the result was that it was given a degree of porosity that made it act ever since?—Well, I will not say that, because we had to take the whole of the drains out, and it never succeeded until the drains were taken out.

4650. But since that the ground has been porous enough to act?—It has; in fact, it is found that that ground properly laid out with a proper fall with the constant circulation of water through it, as I have explained how the water does circulate very greatly improves a clay soil in the course of time permits this circulation to take place through it.

4651. Has that old Norwood effluent been analysed?—Oh! repeatedly. The Norwood effluent goes into a very small stream, not more than a ditch, and in dry time it has to carry itself without any other water, and the consequence is that under these severe tests it has never been found to be in a polluted state. It has been most carefully watched by the sanitary authorities, whose district it goes through after leaving Norwood.

4652. (*Major-General Carey.*) With regard to storm water, is not the first rush of storm water very polluting?—Often it is, very.

4653. Should not a certain proportion of the wet weather flow be fully treated as sewage without reducing the periods of rest in the filters?—That all depends upon the strength of the sewage. As I say, it is absolutely essential if sewage is a certain strength that it must undergo a certain process, and for that purpose we propose to use a three minutes' oxygen test to know at the time being what is the strength of the sewage you have got to deal with.

4654. Take ordinary sewage?—You see, storm water, although it appears to be a great bugbear, is not such a big thing after all the volume, because if all the rain, for instance, in London is added together every minute that it falls throughout the year it does not come to an average of more than twenty days in the year, so that it is not a very serious matter altogether.

4655. If it would be regular in the pollution, but of course when the storm does come, the pollution may be very great?—That is so; it is intermittent.

4656. And treatment of some sort is necessary?—Certainly.

4657. My question is whether the first rush of storm water should not be fully treated as sewage?—It would naturally be so.

4658. Up to a certain proportion?—It would, because the three minutes' oxygen test would show that it was sewage to be treated in a certain way, and it would have to go through that definite treatment; otherwise we should not comply with the standards laid down for our guidance of purification.

4659. What provision is made for dealing with storm water at Friern Barnet?—The whole of the Friern Barnet—there is not a storm water overflow in the district, and all of it goes on to the works, on to the filters. All that happens is that if one filter will not take it it is put on to a second one.

4660. (*Colonel Harding.*) They have a spare area?—We have four areas and probably we use one at a time for a week, therefore we have always got three in hand.

4661. (*Major-General Carey.*) What do you consider to be a maximum proportion of sewage in gallons per acre which can be efficiently purified on a suitable soil, first by broad irrigation after the solid matter has been removed by screening, and secondly with chemical treatment by precipitation?—It would all depend on what is the nature of the soil.

4662. I say a suitable soil?—I would rather treat it by the number of people per acre, the amount of polluting matter, than by the number of gallons, because sewage varies enormously in volume. For instance, take the Croydon sewage; why, when the springs are high, we have often 10,000,000 gallons a day of subsoil water in the sewage.

4663. That is an exceptional case, is it not?—Well, that is a case which we are dealing with on the farm. We have had over 10,000,000 gallons a day. When they are at a low water period we will not have more than 1,000,000 gallons a day in the sewers of leakage.

4664. Do you not think it better to make the proportion of gallons per acre to making the proportion of population per acre?—No, I would say population per acre, because if the sewage is extremely strong it wants an adequate area to take it over. Very dilute sewage, you see, could be passed over a large area, and really the sewage does pass all standards of purification to begin with. In fact, the Croydon sewage itself, when these

springs are high, is actually purer than most of the effluents in other sewage farms.

4665. On page two of your evidence you do not absolutely condemn clay land as useless for filtration?—Oh, certainly not.

4666. You regard it simply as the least suitable?—I regard clay land as—where there is no other land to be got you are bound to use clay land, and the majority of our sewage farms are upon clay soils.

4667. Would you expect a satisfactory effluent to be produced from a small area of clay land with the high rate, say, of 1,000 population to the acre after chemical treatment and precipitation?—Certainly not. I do not think that more than 300 per acre, which was the limit we got to at Norwood, when we had to increase the area; it is as much as ever ought to be put on.

4668. A proportion of 300 to the acre?—300 for clay land.

4669. After chemical treatment?—No; I will not say after chemical treatment.

4670. But I am assuming that there is chemical treatment?—Well, I should not like to say, because I do not think that chemical treatment removes, you see, about 50 per cent. of the impurities, and at the same rate, even in regard to dealing with ordinary sewage, it would want 600 per acre on a clay soil.

4671. Do you consider that these clay soils should be underdrained?—Oh, no; I think a gravelly soil may be underdrained, and deal with enormous quantities of sewage.

4672. You would advocate the underdraining of clay soils and other soils?—Not necessarily so, unless you have got a very large volume of sewage to put on to it. If you have got a sewage of 1,000 people to the acre to put on to the soil it would be absolutely necessary to drain it. You would not get it through; you would not get it purified; it is simply passing it over it at that rate.

4673. With respect to the Norwood farm, which you have referred to at page 3, have not the Corporation recently laid out part of the land for artificial filtration, in order to produce a better effluent?—They have acquired a larger area of land there, and they are making some experiments—bacteriological beds.

4674. In order to produce a better effluent?—No doubt.

4675. They cannot turn out a satisfactory effluent, or sufficiently satisfactory to discharge into the river?—Well, I do not know. I have had nothing to do with them for many years.

4676. You say the work has been working satisfactorily now for considerably over thirty years, producing a very fair effluent. You do not know what the proportion of population per acre is to the Beddington farm?—600 acres are under cultivation. I suppose there would be about 90,000 people draining into that outfall at the present time.

4677. The Friern Barnet filters; is any rest allowed?—Yes.

4678. After the filters are empty?—Yes, one of the four filters is only used probably for a week continuously, and then that is allowed to rest, to dry and rest.

4679. How long?—Until it is required again; then one of the other filters would be used. There are four of them, so they would be used in succession.

4680. Each work continuously for a certain time, then allowed to rest?—Then allowed to rest.

4681. For what period; it may be for a week?—It might be, and if a storm came that you might have to fill all the filters then. I have seen all the filters at work at one time, in time of very severe storm.

4682. But you have sufficient filtering area to allow of complete rest for each filter?—Yes, we have ordinarily, except at an exceptional time of rain.

4683. As to the proportion of population per acre that you treat at Friern Barnet, would it come to about forty gallons per square yard? Is that your maximum limit?—There are about 8,000 people, have I not given you.

4684. 6,000 to 7,000. I am taking it at 30 gallons per head. That comes to about 200,000 gallons per acre?—Well, there is nothing like that volume of sewage at Friern Barnet, ordinary sewage, as the water supply is intermittent and very unsatisfactory in the district, and it is a very strong sewage, and strong sewage is always a difficult sewage to deal with to purify, very much more so than these dilute sewages.

4685. And that has limited the rate?—Yes.

4686. On page 13 you say "that with bacteria beds 3 feet deep, there can be little doubt that the sewage of 10,000 people per acre can be perfectly purified." That would come to about 300,000 gallons per acre?—Yes. The volume of sewage is much greater per head than 30 gallons. The Manchester flow of sewage varied last year from 38 gallons per head per day to 69½ gallons per head per day taken over an average of one week.

4687. Or say 60 gallons per square yard?—Yes.

4688. Do you know that a much higher rate is claimed for the Sutton system of filters?—Well that is as much as I consider, after most careful consideration.

4689. You consider that a maximum rate?—I consider that a maximum rate.

4690. That should be allowed?—Yes, certainly.

4691. And if you increased that rate what would happen?—If you increased that rate you would find that the effluent will not stand this incubator test; that the effluent is liable to undergo a decomposition. I look upon the incubator test as one of the best methods of being able to say whether real purification is taking place or not.

4692. You say on page 14, "It is essential also that after having been in contact, the bed should be effectually drained and allowed time for aeration." What time do you consider essential?—Well, what we are proposing to do in the case of Manchester is to get the sewage on to a bed in half an hour, let it remain in contact two hours, get it off again as quickly as we can, and allow it to aerate them, so we ought to get them filled and emptied in six hours, four times in the twenty-four hours.

4693. That is not four hours rest?—No.

4694. That does not allow four hours rest?—No; it is three hours practically we allow them rest. That would be the maximum that we should be doing.

4695. Or the minimum period of rest?—That would be the average period of rest during the twenty-four hours. At one period of the day, possibly when the sewage is strongest, the time would probably be altered somewhat so as to give a little longer contact, and a little longer period of rest, whereas in the early hours of the morning and in the night time when there is dilute sewage coming down the times might be shortened.

4696. You say that when land is not suitable for the purpose of irrigation, or there is a difficulty in acquiring it, the bacteria bed system offers a complete solution for the purification of sewage?—Yes, that is so.

4697. Have you made comparative experiments to ascertain that fact?—Certainly.

4698. I mean experiments with the land and with bacterial treatment?—I have been making experiments all my life.

4699. You have not been working these bacteria beds all your life?—Well, I have been working at these bacterial beds ever since 1881, after the discovery was made of the organism on the Paris sewage farm.

4700. As regard the practical application of a system of bacterial treatment as compared with land treatment, is not far closer supervision of the process necessary, which it may be very difficult to obtain in small districts?—That is no doubt so. In my judgment the bacterial plan is not adapted to small places, and land would be vastly superior as requiring very little attention. The great essential with regard to bacterial treatment must be the proper supervision of it from time to time throughout the day, which cannot be given in small districts.

4701. (*Sir Richard Thorne.*) Would you tell me if you have come to any conclusion as to the value of crops on irrigated land, whether they do add materially to the value of the irrigation system?—Of course, they give a return which makes the process of irrigation not so expensive.

4702. Do they do anything material as regards the purification of the sewage; the return would seem to imply that they took something up?—No, sir, they do not.

4703. They do not?—It was originally thought so, but it has since been shown to be a fallacy.

4704. And that is your view also?—That is my view entirely.

4705. Would you kindly tell me what precise experiments you refer to when you say that pathogenic organisms cannot percolate into the wells in the neighbourhoods?—I was alluding to that one particularly at Croydon, where there was a great outbreak of typhoid in 1875.

4706. When we did not know anything about pathogenic organisms?—There was the fact that the water was being used for domestic purposes from wells drawn out of

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the gravelly soil in close proximity to the sewage, that sewage containing these pathogenic organisms.

4707. But there was not any proof whatever that the sewage got into the wells, although there was an oscillation in them corresponding to the rise and fall of water on the farm?—There was not the shadow of a doubt the main bulk of the water was from the sewage farm down to the Wandle, and all the subsoil water or effluent from the sewage farm, and these houses were all located in between the bottom of the sewage farm and the river Wandle.

4708. What was the distance between the wells and the parts actually under irrigation?—Some fifty or sixty feet only.

4709. You know of no definite experiments on the point; it is merely an inference from that epidemic?—Well, I should like to say this, that when Mr. Clare Sewell Read and Mr. Thursfield and myself were examining the sewage farms for the Royal Agricultural Society some years ago, one of the things we had to consider was the sanitary condition of those, and in every instance we inquired into the health of the people living upon these farms.

4710. What was the date of this, may we ask?—In 1879.

4711. Again, before anything was known of pathogenic organisms?—Yes; still, although unknown, it was shown that there was not a single one of those farms that anywhere they drew the water supply from wells upon the farm, that there was not a single one on which there had been an outbreak of disease that we could find ever since the farm had been in operation.

4712. They are not experiments; they are mere inferences from certain facts?—Well, they are inferences drawn from what we observed.

4713. You do not mean to say, I suppose, that the pathogenic organisms in sewage are destroyed in the soil?—Well, I have made no experiments to show that that is so or not.

4714. Do you know there are plenty of experiments to show that they are not destroyed?—Well, we know that they have had no deleterious effect after treatment such as they have had on a sewage farm.

4715. May I ask you with reference to your statement to the effect that the passing of sewage through contact beds gave you an effluent absolutely as pure as the water which originally supplied the district producing the sewage; whether that is merely inference, or whether that is the result of actual experiment?—That is, we have been passing it through four times and we get that result.

4716. What result?—The result that the purification is just as pure.

4717. By what test—chemistry?—Chemical test.

4718. Again, there is no direct bacteriologic experiment?—No; we know that enormous numbers of experiments used to be made years ago, that nobody ever went to a sewage farm but what they would always drink a glass of the effluent to show how pure it was. I never heard of any accident happening to anyone who drank it. But thirty years ago it was as common as possible for anyone to go to the Croydon sewage farm to drink a glass of the effluent water, it was so clear and pure to all intents and purposes.

4719. Much the same argument that people use who, escaping on exposure to scarlet fever, declare it is not infectious. But that is a very important statement of yours; I should like to carry it to a logical conclusion. Would not that mean that if you had charge of a number of towns on a river, and you could deal with them as you thought best with regard to their sewage effluent, you could guarantee that the people could drink the river water notwithstanding that any amount of sewage effluent was flowing in just above the water intake?—Provided the sewage effluent had gone through this process.

4720. Provided you managed it?—Certainly.

4721. You are perfectly clear about that?—I am perfectly clear about it.

4722. Do you know anyone else who is?—I do not know.

4723. You bring forward Wycombe as a case in which you say there that the sewage of 1,000 people to the acre has been most effectually purified on the lines which were originally laid out?—Yes.

4724. Do you know that those people are constantly in trouble with the Thames Conservancy because of their imperfect effluent?—Yes, only in recent years, because the population has been enormously increased, and the area of land has not increased. As long as there was 1,000 people to the acre you will find from the result of the investigations they turned out one of the purest effluents that has ever been turned out.

4725. But surely the population of High Wycombe has not enormously increased?—Indeed it has.

4726. Well you know that they have been in trouble for many years past?—I do not know what the trouble is now; I know that the analyses which were put in in the investigation in the Water Inquiry showed the Wycombe effluent to be most satisfactory.

4727. The Chairman of the Public Health Committee says, in 1897, in a printed document, "that the pressure on the Authority by the Thames Conservancy Board renders it necessary that something should be done without further delay."?—Yes; well?

4728. I only ask you whether you really bring forward the High Wycombe case as a typical one of successful result?—All I say is, as long as you confine it to 1,000 people to the acre, there is no difficulty whatever with regard to it.

4729. (*Major-General Carey.*) That would be your limit?—That was the limit, yes.

4730. And that would be the limit now?—That is my limit now, but I believe it is something like 1,500 to the acre at the present moment there.

4731. (*Sir Richard Thorne.*) His Lordship reminds me that I did not definitely ask you on that statement of yours with regard to sewage treatment by chemicals and then passing the effluent through contact beds producing water absolutely as pure as that which originally supplied the district, whether the statement was based on purely chemical experiments, or whether it had anything to do with any bacteriological experiments?—It has to do principally with chemical experiments.

4732. You say principally?—Yes.

4733. How much was not chemical?—The rest is deduction from the chemical process.

4734. No other experiments but chemical?—That is so.

4735. That practically solves the whole sewage difficulty, does it not?—Well, the difficulty would be in getting a place where you could pass it four times in succession. You see you have not the fall in unless the sewage is pumped.

4736. You do not say four; you say a number?—I am thinking of four.

4737. Would that be the minimum?—That would be the minimum to get such a result as that. I am concluding 50 per cent. is removed each time it is passed through a bacteriological bed.

4738. Do you know any place where the levels enable them to get four contact beds after chemical treatment?—I say it could only be done in most cases by pumping.

4739. Do you know anywhere where it has been done?—No; of course not, because it is quite a new thing.

4740. But you gave us the result of it, unfortunately; you say it is absolutely as pure?—We are working three beds at Manchester at the present time.

4741. And does that convert the sewage into water as pure as that which came into the town; I mean is not this pure surmise?—No, indeed, it is not; it must be taken—for instance, now take the water at Manchester—the water at Manchester contains very little mineral water when it comes into the town. It does not apply to the mineral matter in the water, it applies only to the organic impurities in the water which are capable of being removed by a bacterial process.

4742. (*Chairman.*) You have never examined it from the bacteriological point of view at all?—No.

4743. Then I mean you are not stating a fact, but stating what you think would be a fact?—What we know from the chemical analyses.

4744. (*Sir Richard Thorne.*) But how can you refer to chemical analyses if the thing has never been carried out?—We are working three beds together now at Manchester, so we know exactly.

4745. Is the effluent at Manchester as pure as the water which comes into Manchester?—It would, if it passed through another bed.

4746. Quite so; you have not got that additional bed?—It would, if it is passed through another bed.

4747. That is precisely the surmise?—Exactly, because we see now what the law is, that each purification reduces the impurities 50 per cent.

4748. I am not objecting to your surmises, I only wanted to be clear that they are surmises?—It seems to be a law that by each one of those beds, you can improve the impurities from the previous beds by 50 per cent.

EIGHTEENTH DAY.

Tuesday, 21st March, 1899.

PRESENT:

Sir RICHARD THORNE THORNE, K.C.B., F.R.S. (in the Chair).

Professor MICHAEL FOSTER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

Mr. C. J. WHITTAKER, called in; and Examined.

Mr. C. J. Whittaker
21 March 1899.

4749. (*Sir Richard Thorne.*) You are, I believe, Whitworth Scholar, 1880; Chairman of the Accrington and Church Outfall Sewage Works; engineer and chemical manufacturer?—I am.

4750. Will you kindly describe from the very beginning the works which have been carried out under your supervision at Accrington?—The existing works were sanctioned by the Local Government Board in 1886, opened in May, 1889; Plan A shows the works, as originally carried out, consisted only of five tanks, two of which, Nos. 1 and 2, were used as precipitation tanks. From these, the sewage, after remaining quiescent for a short time, was drawn off alternately into one or other of the remaining three large tanks, Nos. 3, 4, and 5, where it was allowed to settle. The clarified (or partially clarified) sewage was then run off directly into the river. The deposited sludge left at the bottom of the tanks was run on to the waste land adjoining, and also into a disused quarry. A small quantity of lime was added to precipitate the solid matters contained in the sewage. The process was to slake the lime on the floor by adding just enough water to cause it to fall to a dry powder. It was then screened and raised by a chain hopper arrangement to the mixer, into which it was converted into thin milk of lime, by being agitated with some of the raw sewage pumped up for this purpose. The milk of lime was then conveyed to the outfall sewer, where it was incorporated with the rest of the sewage by means of a rotating paddle. No means, however, were adopted for artificial filtration, whereby the soluble matters of the sewage might be rendered innocuous, nor was anything done to deal with the sludge. I was appointed Chairman to the Board in 1894, the plans for alterations to the works were approved by the Board, and work commenced in September, 1895. On reference to the plan it will be seen that the main outfall sewer, which is 6ft. 0in. × 4ft. 9in. discharges the sewage into a screening chamber where the detritus is deposited; this chamber is provided with a wrought iron grid or screen to prevent floating matter and large substances from passing forward into the precipitation tanks. A revolving fork arrangement cleans the screen by lifting the deposited material to the surface. The chamber has also a hopper dredger for the purpose of removing the detritus that accumulates at the bottom. Leaving the screening chamber the sewage passes along the mixing channel, underneath the laboratory and mixing house, to the main channel alongside the precipitation tanks. The mixing channel is divided longitudinally by means of an iron upright plate to which are fixed baffle plates. The chemicals are added separately near the screen, the milk of lime to the narrower portion of the channel, and the copperas to the larger section. The two portions of sewage charged with these chemicals unite at the channel adjoining the precipitation tanks and here become mixed.

4751. Will you kindly tell us what that was mixed with?—Lime, copperas and alumino-ferric are used as precipitants. The mixing room is provided with two pneumatic lime mixers and two pneumatic copperas or alumino-ferric mixers, to supersede the old lime mixer. In the former the lime is added in lump and is slaked by excess of water. the milk of lime thus produced is kept agitated and of uniform consistency by a current of air forced from the engine-house. A similar arrangement is provided to the copperas mixers. The liquids are run into separate channels and delivered into the sewage as already described. The water for mixing purposes is forced from a well in the engine-house into which it is run from the effluent tanks, and is delivered into a cistern in the mixing house and here distributed. The shed for the storage of chemicals is at the entrance of the mixing house. After the sewage has been chemically treated it is run into the precipitation tanks 1 and 2 alternately, passing along the channels shown on plan in the direction indicated by arrows. These tanks are provided with screen walls near to the side of the tanks to prevent as far as possible the accumulation of scum in the larger portion of the tanks. The sewage is discharged into the tanks over the edges of cast iron channels; at the bottom of the tanks underneath these channels the bulk of the sludge is deposited, and afterwards drawn off through the mains into the sludge sump. After the treated sewage has remained for some time quiescent, and become to a great extent clarified, it is drawn off by the floating arms into the effluent tanks Nos. 1 and 2 alternately. These tanks are also provided with screen walls similar to those already described. It overflows from these tanks into effluent tanks Nos. 3 and 4 respectively. From these the effluent overflows into the chambers adjoining the roughing filters. A portion of the effluent from tanks Nos. 3 and 4 is run into the well in the engine-house and partially utilised for mixing chemicals. The dimensions of the precipitation and effluent tanks are as follows, viz.: —

Precipitation tanks—

No. 1—101ft. 9in. × 59ft. 8in. ...	674½	square yards.
No. 2—101ft. 9in. × 59ft. 8in. ...	674½	,,
Total area... ...	1349	

Capacity in gallons—

No. 1	254,450	gallons.
No. 2	254,450	
Total area	508,900	

Effluent tanks—

No. 1—101ft. 8in. × 58ft. 2in. ...	657	square yards.
No. 2—101ft. 8 in. × 58ft. 2in. ...	657	,,
No. 3—101ft. 0in. × 74ft. 2in. ...	832	,,
No. 4—101ft. 0in. × 74ft. 2in. ...	832	,,
Add two chambers alongside roughing filters each 101ft. 0in. × 5ft. 0in....	112	,,
Total area... ...	3090	,,

Capacity in Gallons—

No. 1	305,670	gallons.
No. 2	305,670	,,
No. 3	380,520	,,
No. 4	380,520	,,
	1,372,380	,,

The roughing filters are composed of coke supported on steel girders and cast-iron gratings, being sufficiently raised above the floor to admit of ventilation, inspection, and cleaning. They are in duplicate, each divided into four compartments, the effluent passes upwards through the coke, which is 4ft. 8in. in depth, and runs over at the top and down the outside walls of the filters into the channel leading to the secondary filters—see drawings. The effluent can also be drawn off by means of 18in. valves fixed at the bottom of the filters; this will allow the filtering material to become aerated and have rest. There are six filters constructed of coke, having a depth of 2ft. 9in.; these can be worked intermittently, being in duplicate. Each filter is provided with a screen wall

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perforated at the bottom, and situate at that end of the filter near the outlet. The effluent passes through these perforations and flows upwards and runs over the perforations on the top of the wall of the filter into the next filter. This process is repeated until the purified effluent reaches the final outfall channel, down which it runs to the outfall chamber, and is then discharged into the river. Each filter has two valves, by which the water can be drawn off as may be desired, thus enabling the filters to have rest and aeration. The following particulars show the sizes and contents of the various filters, viz.:—

COKE ROUGHING FILTERS.

Superficial Area:

No. 1—4 Chambers, each 44 ft. 2 in. × 24 ft. 1 in., 118 square yds.	= 472 sq. yds.
No. 2—4 Chambers, each 44 ft. 2 in. × 24 ft. 1 in., 118 square yds.	= 472 sq. yds.
Total area	944 sq. yds.

Cubical Contents:

No. 1—4 Chambers of coke, each 184 cub. yds.	= 736 cub. yds.
No. 2—4 Chambers of coke, each 184 cub. yds.	= 736 cub. yds.
Total contents	1472 cub. yds.

COKE FILTERS.

Superficial Area:

Filters A, B, C, each 74 ft. 2 in. × 59 ft. 7 in.	= 1458 sq. yds.
Filters D, E, F, each 74 ft. 2 in. × 61 ft. 2 in.	= 1470 sq. yds.
Total area	2928 sq. yds.

Cubical Contents:

Filters A, B, C, quantity of coke each, 447 cub. yds.	= 1341 cub. yds.
Filters D, E, F, quantity of coke each, 451 cub. yds.	= 1353 cub. yds.
Total cubical contents	2694 cub. yds.

Total area of coke filters combined	3872 sq. yds.
or	34848 sq. ft.
Total cubical contents of coke filters combined	4166 cub. yds.
or	112482 cub. ft.

At my suggestion instead of using the roughing filters.

4752. (*Professor Foster.*) Before you speak of the change would you kindly state what was the result of this system in the quality of the effluent?—During this period the only results that were taken by the Works Chemist were for oxygen absorbed. The diagram No. 3 is for June, 1898, which shows a fluctuation in the strength of the sewage from day to day, from June 1st to June 30th. The black line shows the oxygen absorbed in the raw sewage; the blue line is the oxygen absorbed in the tank effluent; the red line is the oxygen absorbed in the final effluent. The green line at the bottom is the rainfall. You observe the effluent is best when the rainfall is greatest.

Appendix No. 20 (No. 3).

4753. What is the range of the figures indicated by the diagram?—The best effluent we got during that time is 1·5 of oxygen absorbed and the worst is 5 of oxygen absorbed; the range being from 5 to 1·5.

4754. (*Sir Richard Thorne.*) That is the effluent from the filters?—That is the effluent from the filters.

4755. (*Major-General Carey.*) Is that one and a-half millions without storm water at all?—Without storm water at all.

4756. Then you have an enormous rate per square yard; you have 1,600 gallons per square yard?—Yes; I may point out that the rough beds were worked fifteen hours and rested nine. That is, the sewage was allowed to flow fifteen hours continuously through the rough beds and were then rested nine hours. The finishing filters were allowed two hours to fill, and the sewage was then allowed one hour in contact with the filters; three hours were allowed for emptying and six hours for aerating. That was at the rate of 96 gallons per square yard. Even then when the works were in this stage, we had a certain portion of the sewage passing away from the works, only treated chemically, being simply tank effluent, the blue line showing the amount of purification effected.

4757. (*Professor Foster.*) You did not determine the albuminoid ammonia?—No, another diagram No. 2 is for May.

Appendix No. 20 (No. 2.)

4758. With the same general result?—Yes, with the same general result for May and June—the two charts. Diagram No. 3 shows the working of the beds after stopping the upward filtration. In the first place we converted two only of the rough beds into sprinkling filters, and worked the remaining two roughing beds by another method.

4759. May I ask you what led you—it was you who instituted this sprinkling process—may I ask you to state the line of thought which led you to suggest that process?—Well, I may say that in 1894 a system of plans was prepared and applications made to the Local Government Board to borrow money for the alteration of our works, which were simply purely chemical precipitation works. Our chemist, Mr. Barnes, was instructed by the Board to perform certain experiments—to put down small experimental filters. There were three put down. One was an ordinary polarite bed, another was a sand filter, and another was a clinker—a small clinker filter. The precipitated effluent was passed upon these, and Mr. Barnes presented his report to the Board. That report clearly proved that we were getting equally good results with clinkers as we could with polarite. It was just the international method that was suggested. I took my stand against this, and called the two constituent authorities together and pointed out that they were going to spend £6,000 or £8,000, which would be practically money thrown away when they could get equally good results with coke. The position I took up meant that the then chairman and one or two of the members resigned, and I was put in as chairman. I said that however efficient and however good a method of works might be adopted, it would be absolutely necessary to have a resident chemist to see that the work was thoroughly carried out, and not an ordinary works manager. At my suggestion the borough engineer, Mr. Newton and Mr. Barnes were appointed to prepare plans on lines that I said would work out equally well with the international system people. Plan No. 1 shows the arrangement of their working out.

4760. The essential feature of your system as in the present action is the continuous sprinkling?—Yes.

4761. What led you to the idea of continuous sprinkling?—After the chemist and the engineer had carried out their work, the works seemed to be as great a failure as ever. I felt then, as chairman of the works, that I had got to do something or be disgraced.

4762. (*Sir Richard Thorne.*) You say they were as bad as ever—does that mean chemically?—The final effluent.

4763. Judging by the final result?—Judging by the absorption of oxygen. That is, the rivers inspector said the effluent was as bad as it was with chemical precipitation alone. I then set to work at my own chemical works at Church and had a filter fitted up, and carted to my own works an average sample of the sewage. I had twelve forty-gallon barrels of sewage carted from Coppy Clough to Globe Chemical Works daily, and set my filter in motion. When I first of all started that I thought I must have uniform distribution. I got uniform distribution. It was an old soap boiling pan which I had filled with small filter material with narrow troughs about four inches apart. I had the sewage pumped into a room above; I had the tap regulated so that I was able to put on to the filter 240 gallons per hour. I found that the sewage practically came through the filter in the same state as that in which it went on.

4764. Two hundred and forty gallons to what area?—To the square yard. I found it was coming out of the filter practically the same as it was going on. I had then the filter material taken out. I put a perforated grid on the bottom of the pan, filled the material into the filter again, put on an air pump and pumped the air into the empty space at the bottom of the pan, so that there was always a current of air passing through the filter. Then I found that we got much better results, and began to have nitrates formed. But still if the tap was turned the least bit over 240 gallons the effluent began to come through the filter almost the same as the sewage. One of the defects I found was that in levelling the troughs the smallest amount of scum or heavy particles covered the edge of the trough, and the bulk of the material would be passing through in one place, so that then I adopted the sprinkler and fitted the sprinkler to the top of the pan and got these results.

4765. (*Professor Foster.*) But, excuse me, why did you make this sudden change from upward to downward filtration?—At the works?

4766. All your experiments that you are relating now refer to downward filtration?—Yes.

4767. At the works there was upward filtration?—In making observations about the works I had samples taken on the top of the roughing filter at various points. I suggested first of all that the liquor was following along the line of least resistance, and although apparently we were having upward filtration there was really no upward filtration taking place; the tank effluent was simply flowing through the open space underneath the filter and rising up through the filtering material at the end of the filter; and it was through taking samples at different parts of the filter that this was found out; I found then that although upward filtration apparently would be good for preventing floccular matter reaching the filter, really it was not acting in practice; there was no upward filtration taking place only at about a yard from the end of the filter, and it was these experiments that led me to alter it to downward filtration. I then asked the permission of the Board to put in an experimental filter at the works, and I put one down twenty yards in area, nine feet deep, and just the length, so that two small sprinklers would fill the space. It was filled with graded material; on a concrete bottom with ordinary 4in. drain tiles, about two feet of sand stone ballast, next the drain tiles, then a layer of coke about three-quarters of an inch mesh, then a layer of ordinary coke 2in. mesh to the top; then about eighteen inches of the top were granite chippings; granite chippings I found were too flat; they did not allow of ventilation, and had to be removed. From the results obtained with the experimental filter, the Board determined to convert one of the roughing filters to the sprinkler system, and this diagram No. 1 for the month of September, 1898, gives some idea of the difference in results obtained in working between the Whittaker filter, the roughing filter, and the tank filter. The black line, again, on this diagram shows the oxygen absorbed in the raw sewage throughout the month, the blue line shows the oxygen absorbed in the tank effluent; the brown line shows the oxygen absorbed after passing through the roughing filter. One-half of the roughing filters only being converted to the Whittaker system, the other half was still worked as a roughing filter.

Appendix No. 20 (No. 1.)

4768. One of the old roughing filters?—One of the old roughing filters. The strong red line shows the oxygen absorbed in the final effluent from the old works after passing the tank effluent through the roughing filter and through the fine beds. The dotted drab line shows the results obtained by downward filtration through the Whittaker filter with only 4ft. 8in. of coke; the drab line shows the purification by upward filtration; the dotted drab line shows the purification by downward filtration. Then after downward filtration, through the Whittaker filter the effluent was allowed to pass on to one of the finer beds, which removed the suspended matter, and it was further reduced to the dotted red line. This diagram simply shows the comparison between the results obtained when working with absolutely the same material and depth of material worked upwards and downwards, giving a difference of two parts per 100,000 in oxygen absorbed between the drab line and the dotted drab line; the same material and the same tank effluent being used.

4769. (*Professor Foster.*) Did you expect that amount of oxygen to be absorbed when you constructed the bed and the downward filter?—No, we were getting a much better result with 9ft. than we obtained by 4ft. 8in. The nitrates were not being determined at that time. It was then decided to convert the whole of the four beds to the Whittaker system. The sprinklers on the two beds were stopped a week and another yard of filter material was put on the top of the already 4ft. 8in., and the whole four beds levelled up to 9ft. deep of coke, and they have now been working continuously since last October.

4770. (*Major-General Carey.*) What proportion of sewage do they take?—With 400,000 gallons about one-third.

4771. (*Sir Richard Thorne.*) And that is by the sprinkler working day and night?—By the sprinkler working day and night.

4772. (*Major-General Carey.*) How is the rest of the sewage treated?—A portion is still passing on to the finer beds. A portion is being treated by the finer beds and a portion is being treated and passing into the river simply treated in the tank. Referring to diagram No. 2 B for February, the light red line C shows the temperature of the raw sewage as it comes into the works; the low bends are when we have had snow. It evidently loses about three degrees in passing through the works. The lower line D shows the temperature of the tank effluent; the higher line A shows the temperature of the sprinkler; and the next line B shows the temperature of the final effluent. The temperature of the final effluent is always less than the temperature of the sprinkler. No. 2 B diagram also shows the oxygen absorbed test. The black line is the oxygen absorbed in parts per hundred thousand in the raw sewage. The blue line which crosses the black line is the oxygen absorbed in the tank effluent. These show the difference between the raw sewage and the tank effluent. The red line is the oxygen absorbed in the final effluent.

Appendix No. 20 (No. 2B.)

4773. (*Professor Foster.*) The high temperature of the sprinkler is due to the steam in the pulsometer?—Yes. The bottom red line on this diagram shows the oxygen absorbed in the final effluent in three minutes, before incubation, and the dotted red line just a little above it is the oxygen absorbed after 5 days' incubation at 80° F. Now the tank effluents are also incubated. The bottom yellow line is the three minutes' test of the tank effluent before incubation, and the upper yellow line is the three minutes' test of the tank effluent after incubation. The final effluent lines, before and after incubation, are almost parallel, and show the small amount of decomposition that takes place. In order to see the effect on the test of the suspended matter each effluent is filtered, and the dotted red line shows the oxygen absorbed free from suspended matter, diagram No. 2B showing the oxygen absorbed only, and diagram No. 2A shows the albuminoid ammonia tests for the same month. In order that these shall appear clearer, in the diagram the albuminoid ammonia is shown in parts per million. The black line is the albuminoid ammonia in the raw sewage, the highest point being 1·3, 1·4 and 1·6 parts per 100,000. The dotted black line is albuminoid ammonia in the tank effluent, the average of which will be between 0.8 and 0·9. The great depression is caused by heavy rainfall; the red line showing the rainfall. The dark blue line shows the free ammonia in the raw sewage, and the dotted blue line shows the free ammonia in the tank effluent, which is invariably higher.

Appendix No. 20 (No. 2A.)

4774. Before you introduced your system you were using copperas and lime as a precipitant?—Yes.

4775. Now you only add lime as a neutraliser?—That is so.

4776. Does the diagram show the result since the change?—Yes, and on to the sprinklers.

4776. Since you have adopted lime only as a neutraliser and dropped the copperas altogether?—Since we have dropped the copperas altogether and use no chemicals now, only a little lime to neutralise the acidity.

4778. (*Sir Richard Thorne.*) What amount per million is used?—Ten cwts. to one-and-a-quarter million gallons; that is five or six grains to the gallon. The nitrates are shown on the chart by the green line.

4779. (*Colonel Harding.*) What is the figure they leave as an effluent?—Here we have 2·7, and here we have 2·6. Perhaps 1·7 is an average.

4780. (*Sir Richard Thorne.*) Of nitrates?—Nitrogen as nitrates.

4781. But not as nitrates?—No, we take them both together.

4782. You take them both together?—Yes.

4783. Then it means nitrogen as nitrates and nitrites?—Yes; it ought to be nitrogen as nitrates and nitrites. Now after incubation the green line falls as shown by the dotted green line, and in some instances the lines touch, but invariably the nitrates decrease during incubation, the nitrates disappear during the five days of incubation on the 23rd, 24th and 25th, but the albuminoid ammonia was correspondingly high. The average of the albuminoid ammonia in the final effluent will be about ·12 or ·13—something like that.

4784. (*Professor Ramsay.*) Might I ask you what you regard as the septic tank there?—The tank effluent.

4785. You treat the previous settling tanks as septic tanks?—That is all; yes. We regard the flow through the tanks only as anaërobic action; we simply add a little lime, and allow it to flow through the tanks. My

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opinion of dealing with sewage efficiently is that you want a sewage reservoir, just the same as you have for collecting the water before it is delivered to the town. That is, you want a reservoir for storing the sewage before you deliver it to the filters.

4786. (*Professor Foster.*) In the reservoir of a town there is no changing, but in your septic tanks surely a very great change has taken place?—Yes. That change takes place before it passes on to the land or to the filter.

4787. It is flowing continually through your septic tank?—Continually passing through.

4788. How long does it take to pass through?—About 24 hours.

4789. Always passing through?—Yes.

4790. And there is a continual deposit of sludge at the bottom in that septic tank?—Yes, after the decomposition of the sludge has gone on for several days, it begins to rise to the surface in the form of a thick scum of fœtid matter.

4791. But that runs over the lip of your septic tank?—No. Wherever there is an opening there is a screen to prevent the scum from passing over. None of the liquors are drawn off only at about a yard from the surface.

4792. Since your system has been in action what is the amount of sediment which has taken place in your septic tank?—By analysis?

4793. No; the amount, the depth?—At the present moment after the tanks have been working for 12 months you can hear the sound of the rake at any part of the tank; that is, there is very little sediment. It is a difficult matter, but I have endeavoured to take a sample right at the bottom and there appeared to be about two inches of black gelatinous matter that you could scarcely call sludge, that you could not press; as it liquefies the solid portions only rise to the surface.

4794. Floated up by gas?—Floated up by gas.

4795. Does it get blown away or go to the side?—During rough weather it blows to the side, and on still days the whole of the surface is covered with a spongy mass.

4796. With a very powerful odour?—Scarcely any odour; practically no odour.

4797. (*Sir Richard Thorne.*) Does the amount of the sludge depend much upon whether the surface of your open septic tank is, so to speak, roofed in by this material that floats on the surface?—No, not at all.

4798. Where there is none of that coating on the surface do you not get any more sludge than when it is coated over?—No. As the sludge slabs reach the top they seem to be broken up into a substance that almost corresponds with soot from the change of the colour. You notice the crude sewage coming into the works will look quite soapy, while from the second tank it is quite black, almost as though it were mixed with soot. It is the fine particles of vegetable and animal matter that have been decomposed that give this black sooty appearance.

4799. (*Professor Foster.*) Is your scum black in colour?—Yes, very black; almost like ink sometimes.

4800. (*Professor Ramsay.*) Is there much soap or grease in the sewage?—Yes, a fair amount of soap. We have a very strong domestic sewage; we have 8,000 water-closets that are on what is called the waste water system. In fact, our average per head of the population is only about 20 gallons; that is, the average quantity of water used is about 20 gallons per head.

4801. (*Sir Richard Thorne.*) Does all this mean that you do not attach any value to the roofing in of the septic tank so far as the anaërobic action is concerned?—There is no necessity to roof in so far as the decomposition is concerned. The oxygen does not readily pass into the body of the water.

4802. (*Professor Ramsay.*) Nor the light?—Nor the light.

4803. (*Professor Foster.*) So that in your opinion the only thing would be to prevent any gases going into the atmosphere?—It might be a useful gas for the purposes of heating or lighting or anything of that sort, but I do not think any actual benefit in the act of decomposition is secured. I think it is shown by the diagrams. In fact, I may say that I have never seen any such result as we are obtaining at Accrington before. Diagram No. 2A shows the free ammonia in the raw sewage, and also the free ammonia in the tank effluent, which has invariably increased. I may say that I have never seen that in any case before. I have always had it pointed out that the free ammonia had diminished, and some purification taken place in passing through the tank, whereas in this case the free ammonia actually increases in quantity.

4804. Has any examination been made of the gases in your tank?—I have made several analyses. They are chiefly marsh gas. I have also made attempts at the gas from the filter; several have been made, and we have not up to now been able to find any serious diminution in the quantity of oxygen in the body of the filter.

4805. (*Professor Ramsay.*) Which filter?—In the body of the sprinkler filter; we have not been able to determine any loss in the oxygen, although as a matter of calculation the quantity of nitrates and the amount of oxidisation that takes place—which is measured by the diminution in the oxygen absorbed—the nitrates and the oxygen absorbed are equal to twice the amount of oxygen contained in the interstices of the filter; so that the interstices of the filter must be replaced by entirely fresh air at least twice per day. But seeing that it is difficult to determine any small diminution, it means that the air must have been changed several times in the body of the filter daily.

4806. (*Professor Foster.*) That is to say, you have made a (I suppose it can only be rough) calculation of the amount of air which is present in the interstices of your filter?—Yes. We have put in a pipe four feet into the filter, and connected that with an aspirator, and then we have estimated the carbonic acid and the oxygen.

4807. You have not made any estimate as to the total available oxygen which is present in the body of the filter at any one moment?—Yes. That is the only way you can take a sample, by aspirating through a pipe which you drive into the body of the filter.

4808. From that sample you have calculated?—From that yesterday I got 21 per cent. of oxygen.

4809. How much carbonic acid?—We did not find any carbonic acid.

4810. Have you ever emptied your open septic tank yet?—We have lowered it. We commenced last February, and at the beginning of July the Committee were so anxious to see what was taking place that the septic tank was let off in July, but from last July till now the tank has never been emptied.

4811. When you emptied it what did you see?—We worked from the beginning of February to the beginning of July, and there was not as much sludge in appearance or in quantity as there would have been in one week's chemical precipitation.

4812. (*Professor Ramsay.*) What becomes of the lime you put in?—It chiefly passes away.

4813. Dissolved?—Yes.

4814. (*Professor Foster.*) So that you have not been making any sludge cake at all?—The sludge presses have not been used since last February. The little sludge which was in the septic tank was run into a small lagoon that we had.

4815. (*Professor Ramsay.*) Does the lime form lime soap?—Yes.

4816. That effluent forms a cake on top?—It forms a cake on top.

4817. (*Major-General Carey.*) Has there been any reduction in the water capacity of the filter?—We have no occasion to measure the capacity. It is not the capacity we work upon; it is simply upon a thin film. So long as there is an air passage for this film the capacity is immaterial. It would do so far as we are concerned if the filter was composed of a number of small drain tiles 2in. in diameter.

4818. You pass the same quantity through daily?—The same quantity passes through.

4819. You pass the same quantity through after six months as you did on the first day?—Yes, that is so.

4820. (*Colonel Harding.*) If your bed became sludged up then your sewage would not pass down; it would run over the top and over the sides?—Yes, that is so. Our filters, although the tanks are square, the corners have been cut away, so that there is simply filtering material

along the surface, so that if it were made up at all it would accumulate on the top, flow over the sides, and run down the sides necessarily, but there is not the slightest sign of that taking place.

4821. (*Sir Richard Thorne.*) After how long a period?—Since August (eight months).

4822. Of day and night use?—Of day and night use.

4823. (*Professor Ramsay.*) Is the temperature of the filter higher than that of the air?—The heat of the filter is generally seven or eight degrees warmer. During this cold weather we make it ten degrees, during warm weather it may be only five degrees; the heat given by steam in the pulsometer.

4824. (*Professor Foster.*) You regulate the temperature of the filter by the pulsometer?—By a separate jet of steam besides the pulsometer.

4825. (*Major-General Carey.*) At what rate do you work per square yard of your filter?—We filter 600 gallons of settled sewage to the square yard, and that is when sewage is about 0·4 albuminoid ammonia per 100,000. We have just had some rather dry weather; we have had a whole month not only of cold, but dry weather, and our tank effluent reached 1·1 of albuminoid ammonia. On account of the albuminoid ammonia in the final effluent getting up, we reduced the flow to about 400 gallons. You see you have the means of checking it. The time when the albuminoid ammonia rose to 1·1 was exactly a week after we had stopped the addition of lime altogether. On the 22nd February we found that the whole of the tanks had become quite distinctly acid; we had had the lime stopped just a week; we commenced immediately to add lime again, and it took us four or five days before the lime had got thoroughly through the tanks.

4826. (*Professor Foster.*) What was the effect of the abstention from lime on the nitrates?—The nitrates were reduced, while the albuminoid ammonia went up.

4827. (*Major-General Carey.*) Do you have storm water in the filter?—The whole of the water which comes down the sewer passes through the tanks.

4828. Not through the filters?—Not through the filters. It is a perfect average of all the sewage that comes to the place. The filter takes off that, whether it be storm water or not, 400,000 gallons per day.

4829. (*Sir Richard Thorne.*) Then so far as the capacity is concerned it takes storm water as well as sewage?—Yes.

4830. (*Colonel Harding.*) But not all of it?—That is so, when the tank effluent got down to this low point 0·37 on February 15th, that is, after very heavy rain, the filters were put on at almost 1,000 gallons to the square yard.

4831. (*Professor Foster.*) Have you ever determined these two points: One is the amount of fluid which you will throw on to your filter which cannot pass at all; and, secondly, the amount of fluid which you can throw on to your filter which will pass, but in passing distinctly alters the character of the effluent?—Yes, we have tried that.

4832. Both those points?—Both those points. We have put it on to the extent that the distribution has been greater than the areas of flow in the filter, and that is reached at about 1,200 gallons to the square yard; that is when we put on 1,200 gallons to the square yard the films are too thick, and the body of the filter seems to become water-logged, and at the top you have a pool for the moment.

4833. But short of that you may increase the quantity so as materially to influence the character of the effluent?—Yes. Here with a tank effluent, 1·1 for instance, had we to have put on 1,000 gallons to the square yard we should then have had a very muddy and cloudy effluent, because it was so strong that it would have been utterly impossible for the filter to have dealt with it.

4834. But you would affect the effluent before you reached the 1,000?—Yes.

4835. What is the point at which your filter ceases to have its maximum efficiency?—The efficiency of the filter continues as you diminish the quantity.

4836. But what is the limit to the increase of fluid which you put upon your filter which reaches the point at which the filtrate begins to suffer?—With about ·5 of albuminoid ammonia we say that 600 gallons is the limit to which you ought to go. If you want a better effluent, come down from 600 to, say, 400. But if you increase it above the 600 you then begin to get an unsatisfactory effluent. That is we say satisfactory, because we work at ·1 per 100,000.

4837. The efficiency of your filter depends naturally upon the strength of your sewage?—Yes.

4838. And you can regulate the quantity which you can throw on your filter consistent with having a good effluent according to the concentration of your sewage?—That is so. Every point can be regulated—the flow of the sewage, the temperature of the sewage, and the temperature means the aeration of the filter.

4839. (*Major-General Carey.*) If you are designing a filter to take the ordinary dry weather flow, you design is at the rate of 400 gallons per square yard?—Yes.

4840. That would be your unit?—Yes.

4841. (*Colonel Harding.*) That must vary according to the strength of the sewage?—Yes. You might say that most sewages will go to 1·0 of albuminoid ammonia at times, and you want to take the higher point.

4842. (*Professor Foster.*) 400 gallons leaves you a margin?—Yes. We can practically put on 600 gallons at ·5. ·5 of albuminoid ammonia is a fairly average sewage, and 400 gallons will give you a very good margin; it will allow you to go up to 1·0.

4843. Have you made any observations in reference to temperature; do you find that your filter is rendered more efficient by raising the temperature?—Yes. I may say that we have worked with the temperature up as high as 100° F.

4844. With what result?—Nitrates at 4, 5, and 6.

4845. As compared with what?—With nitrates at 2 say, at 60° F.

4846. What is the result of, say, a temperature at 60 compared with a temperature at 100?—The nitrates will be more than doubled.

4847. At 100 Fahrenheit?—Yes.

4848. (*Colonel Harding.*) And what is the effect on the albuminoid ammonia and the oxygen absorbed?—They go just accordingly: the more nitrates you have the further the albuminoid ammonia and the oxygen absorbed go down. I have not those in chart form.

4849. Do you think you could meet changes in the strength of your sewage by changes in temperature, by simply raising the temperature when the sewage was stronger?—Yes. That is one of the chief advantages, I think. Here you have a pump that you can slow down to 400, or that you can increase to 1000; and the person who is in charge of the laboratory can go out and say "put it on at 500;" "put it on at 600;" "put it on at 800;" and put it on at 1000," according to the strength.

4850. (*Professor Ramsay.*) Does the rapid working of the pump increase the amount of heat given to the sewage?—The rapid working of the pump simply increases in proportion.

4851. (*Colonel Harding.*) Increases the flow?—Increases the flow, but keeps the temperature the same; the temperature is the same with a quick flow as with a slow flow, because you want so much more steam to do the work.

4852. (*Professor Ramsay.*) Can you increase the temperature?—We can increase the temperature.

4853. Apart from the flow?—There is a supplementary steam jet to increase the temperature.

4854. (*Colonel Harding.*) Have you formed any view as to the cost at which these results as to heat can be obtained?—We have now been working for some three months, and all the coals that have gone on to the boiler have been weighed, and about 10 cwt. of coal is required to raise the temperature of 1,000,000 gallons one degree, so that to increase the temperature five degrees would take 50 cwt. of coal in 24 hours.

4855. (*Sir Richard Thorne.*) At Accrington did you get the boiler solely for the purpose of the sewage works or did you use it for a destructor or anything?—It was put down originally to drive the sludge-pressing machinery.

4856. If you had a destructor at work I suppose the same boiler would heat it with considerable economy?—Yes. You could obtain the whole of the heat you would require from a destructor; the whole of the heat could

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be obtained from the refuse of the town, that would be sufficient to warm the whole of the sewage.

4857. With very little fuel added to the refuse?—With practically no additional fuel.

4858. (*Major-General Carey.*) What do you find to be the cost per million gallons—capital expenditure?—About £3 per yard per 600 gallons.

4859. Per square yard of filter?—Yes; about £3.

4860. (*Sir Richard Thorne.*) That is the original outlay?—Yes.

4861. (*Major-General Carey.*) That includes everything—the whole of the capital expenditure?—Yes, boilers, chimneys, pumps, sprinklers, filtering material, draining bottom of the tanks.

4862. (*Colonel Harding.*) Will you say what filtering material?—Yes, my estimate is based upon coke as being practically as cheap as clinker.

4863. (*Professor Foster.*) Have you tried any other material than coke?—I have tried ordinary ballast, sandstone, and granite chippings.

4864. (*Major-General Carey.*) Cinders—ordinary cinders?—Yes.

4865. (*Professor Foster.*) With what result?—We find it is best to have something large; something about one and a half inches or two inches, and coke is the material that gives you the size best. It is the size that determines it, not the nature of the material.

4866. Have you tried finer material at all?—With the finer material the flow at which capilliary attraction begins to work is so small and you cease to have the air passages; you must have the passages for free films.

4867. Your installation has been going on now for thirteen months?—Since last June.

4868. Not since February?—The tank since February.

4869. But the filter since June?—The filter since June.

4870. That is eight months?—Yes.

4871. Are the results during the last two months quite as good as those during the preceding months?—Quite as good as during the first month; they are equal now to anything we have had.

4872. Have you dug into your filter at all; have you displaced any part of it?—Yes; we have dug down several times, and when we get to about three feet the coke seems to be practically as good as new; it only seems to affect the coke for about three feet of its depth, so far as any jelly showing on the surface.

4873. Did you see the same thing in bed No. 1?—Yes.

4874. Was it different from that?—It is of a much blacker nature: quite a black slime.

4875. For about three feet?—For about three feet.

4876. But below three feet?—There is practically no difference in the material from when it was first put in.

4877. The coke is, so to speak, clean?—Perfectly clean in appearance.

4878. Do you think that the greater part of the work is done in the upper layers?—The greater part of the work is done in the upper layers. I may say that the effluent always contains in our sewage a fair amount of sediment or suspended matter.

4879. (*Colonel Harding.*) How much?—Perhaps the total will be about 70, I think.

4880. In the sewage?—No.

4881. The total solids?—Yes.

4882. Including those in solution?—Yes.

4883. (*Professor Foster.*) 70 in 100,000?—Yes, the total solids in the filter dried at 110°C., about 70; they vary from 64, 71, and 72.

4884. To the 100,000?—To the 100,000.

4885. (*Colonel Harding.*) How much in suspension?—The suspended matter in the filter 2·5.

4886. In the filtrate?—In the filtrate, 1·5, 3 and 2·5. Taken from Mr. Naylor's report.

4887. (*Professor Foster.*) Per cent.?—Per 100,000.

4888. Per 100,000?—Yes. The matters in solution are, as a rule, greater in the effluent. The total dissolved matter in the final effluent is, as a rule, higher than the total dissolved matter in the tank effluent.

4889. What proportion of that is borne to the nitrates?—I have not calculated that.

4890. A considerable portion, I suppose?—I should fancy so; yes. With regard to the cost, I may say that when using precipitants at the rate of one ton of lime and copperas per million gallons.

4891. But you do not use them now?—No, but this report I am quoting from was presented by the Chief Inspector to the Ribble Joint Committee, and in comparing the cost of working, he gives lime and copperas £2 10s., pressing 40 tons of sludge, £1; which gives a cost of £3 10s. per million gallons treated; while with the new treatment, he takes one ton of lime, 10s., supposes the sludge 13 tons, and puts 5s. for pressing, and coal £1 5s., or a total cost of £2 per million.

4892. I thought you had no sludge at all?—This is Mr. Naylor who is making an estimate with regard to the cost, so far as its inclusion within the regions of "the best known reasonable and available means" is concerned. He is taking it at its worst.

4893. He is taking it untruthfully?—Yes.

4894. You say there is no sludge?—Yes, he is not only doing that, but he has taken the lime, although he has been told repeatedly that we are only using 10 cwt. of lime; he has put in 1 ton of lime, and the sludge 13 tons; the coals at 25 cwt. The cost formerly was £3 10s. as against £2; but there would be a saving of 30s. a day, and that is making a very bad show of the figures.

4895. (*Sir Richard Thorne.*) What is your estimate as to what the contrast is between £3 under the old system and your system?—My estimate is that they will save at the very least £2 a day.

4896. That is the difference between £3 10s. and £1 10s. a day?—Yes; between £3 10s. and £1 10s.

4897. (*Colonel Harding.*) What does Mr. Naylor say of your final effluent?—He puts it amongst the "fair" in his list.

4898. Not among the "good"?—No. He says a great advantage would be some sort of mechanical strainer for the little suspended matter in the filter effluent, for though small in amount it affects the result to an appreciable extent; when devoid of this albuminoid ammonia it yields only ·08 instead of ·16.

4899. Is the suspended matter albuminoid ammonia then?—It counts as albuminoid ammonia in the test. It consists of 58·5 per cent. of mineral matter and 41·5 of organic matter.

4900. (*Sir Richard Thorne.*) There has never been any bacteriological test of your effluent?—None at all, no. It has been put under the microscope from time to time. The effluent always seems to be highly charged with much higher forms of life than bacteria. For instance, we get any number of cyclops.

4901. (*Professor Foster.*) As it is passing through?—Yes.

4902. (*Professor Ramsay.*) You have got accounts, I suppose, of the amount of nitrates and albuminoid ammonia?—Yes; these are made daily now.

4903. You will submit these to the Commission?—Yes. you can have copies of any of these. These are for each day, and they are much better than figures. For instance, there you have 5·4.

4904. (*Professor Foster.*) That is the daily move?—Yes. from the 1st to the 28th of February, and the samples are all average samples. A sample is taken both of the sewage, tank effluent, and of the filter effluent.

4905. (*Professor Ramsay.*) But do they correspond?—The average ought to correspond. For instance, here is the highest, take that one; that is two days behind.

4906. (*Professor Foster.*) It does not matter, of course?—No.

4907. You have not a table showing the comparison with the coke; you did not do the albuminoid ammonia with the coke?—No, we were quite content with the oxygen absorbed test. Here we have the same comparison with the oxygen absorbed.

4908. I should like to ask you how does this sewage now running on to the bed which we saw outside there compare with the sewage running on your bed?—It is not much more than about one-third of the strength.

4909. Of the raw sewage?—Yes.

4910. (*Major-General Carey.*) That you have at Accrington?—Yes.

4911. (*Professor Ramsay.*) Have you trade effluents at Accrington?—Yes, we have tanneries, leather currying, soap works, chemical works, and bleach and dye works. We have no scouring or anything of that nature.

4912. (*Professor Foster.*) More dyes?—Yes. We have a number of dye extract makers, and we get a fair sprinkling of the washings from logwood and tanning and soap making, and that sort of thing.

4913. Is your filter effluent often coloured?—Never coloured.

4914. (*Major-General Carey.*) No matter what the dye is?—No matter what the dye is.

4915. (*Professor Foster.*) At what stage is the colour lost?—Partly in the tanks; chiefly, I may say, in the tanks.

4916. (*Colonel Harding.*) Is it very visible in the sewage?—Yes; you get it almost like red ink at times.

4917. Do you get blue dyes?—We do not get any blue dyes. I have tried it with blue.

4918. (*Major-General Carey.*) What are your observations with regard to the water capacity of filter at starting?—We have tried ours, and it is a very singular thing that it seems to have been a prevalent notion that if you reduce the dimensions of the material you also reduce the liquid capacity, but it is quite immaterial what is the size of material you use; the liquid capacity remains the same whether you have half-inch coke or three-inch coke.

4919. What proportion is that to the original capacity?—As eight is to seventeen.

4920. (*Professor Ramsay.*) Does it matter in your case?—No.

4921. (*Professor Foster.*) Your filter is a perpetual sieve?—Yes.

4922. Of which you cannot estimate the capacity?—No

4923. (*Colonel Harding.*) You cannot fill the bed?—No; but you can estimate the capacity by taking a cubic yard of the material.

4924. (*Sir Richard Thorne.*) Would there be any object in doing so?—Not the slightest. The difference to me appears to be shown very clearly in an ordinary bed remaining at rest; when you fill it up with sewage you drive the whole of the air out, and all that takes place while the liquor is in actual contact with the bed is for the suspended matter to deposit, and it acts more as a strainer than as an actual purifier, although it is left in contact with the beds. Some little purification goes on on account of the capacity of the bacteria no doubt, but the bulk of the work is done when the bed is run off and the air is brought then into contact with the bacteria, where, as in this case, the tank is always run off; that is, in the sense of always being empty, and the air is always present, and always present in a recurring current on account of the temperature being higher and much greater ventilation taking place. I have tried it, not only with broken material, but I have tried it in an ordinary chemical vessel in a laboratory where you can take shot of different sizes—fine shot, buck shot, marbles, and so on. If you take a vessel and fill it with the various sizes of shot and try the liquid capacity, you find that the same amount of liquid is required whether you use one-eighth inch or half-inch shot.

4925. You were saying that the principal action takes place in the upper three feet of the filter. Why then do you make your filter twelve feet deep?—If you could get it absolutely uniform, so that you would be sure that in each part of the filter the liquor would remain the same length of time, a less depth would be sufficient, but you will find however carefully constructed the filter is, that in one particular spot there will be quite a distinct and direct thread of air, and that thread of air would pass too much of the effluent. The extra depth is only to balance what you might call the irregularities of the filter.

4926. It is a check then?—Yes, it is a check.

4927. (*Professor Foster.*) You said, I think, that a sample of the gas taken from about the middle of your filter—a sample which you believed to represent the condition of the gas at the time, was purely atmospheric air?—Yes, ordinary atmospheric air.

4928. Then the oxygen which the nutrifying organisms had taken out had been immediately supplied?—Yes, in its place.

4929. And what becomes of any carbonic dioxide that forms?—That must be taken up by the little excess of lime.

4930. (*Professor Ramsay.*) Or pass upwards?—Or pass upwards.

4931. (*Professor Foster.*) Did you examine it very carefully; you are sure that there was no indication of the nitrogen in the atmosphere?—Oh, yes; I added the caustic potash first, very carefully levelled without the slightest show of any carbonic acid; then I added pyrogallic acid which gave 21 oxygen; it was very marked.

4932. But there is a loss of nitrogen in the whole process?—Not in the atmospheric air, I suppose.

4933. But in this way, with the nitrogen of your nitrates?—In the nitrogenous material.

4934. A considerable deficiency?—Yes. According to the Kjeldahl method, for instance, the tank effluent gave 6·9 of nitrogen as ammonia, total nitrogen; that was reduced to 4·3. On another day the tank effluent or total nitrogen was 5·22, while the filtrate was 2·7.

4935. Does that mean that the nitrogen has been got rid of somehow?—Yes. Converted into nitrates.

4936. No free nitrogen has been looked for?—Then, for instance, first of all the ammonia is determined.

4937. But the Kjeldahl determines the total nitrogen?—Yes, but we determine free ammonia first, and reduce the nitrates and nitrites to ammonia by the zinc and copper couple.

4938. And in passing through your system there has been a very notable loss of nitrogen?—Yes, as nitrates.

4939. It must be either retained in the body of your filter somewhere—or go off atmospheric nitrogen?—Yes. Or pass away as nitrates.

4940. Probably the latter?—Yes, probably.

4941. You have not tried crude sewage on your bed at all?—No.

4942. (*Professor Ramsay.*) What is the relative area which is covered by your filter compared with, say, the Dibdin process, for disposing of the same quantity of sewage in the same time?—We have at Accrington three-quarters of an acre of tanks.

4943. To deal with how much sewage?—And we shall have three-quarters of an acre of filters; that will deal with 1¼ millions of dry weather flow—an acre and a-half.

4944. One-and-a-half acres to a million-and-a-quarter gallons?—Yes.

4945. (*Professor Foster.*) Have you calculated what area of filter is required per hundred thousand of inhabitants?—I have not calculated that.

4946. (*Sir Richard Thorne.*) Could you compare the area of land that is required for your works, and that required for Mr. Dibdin's?—It would take twice the area.

4947. (*Colonel Harding.*) Are you considering merely the fine bed? You say that it will take a very much larger area for the contact beds, but are you counting double contact beds or simply fine beds?—Double contact beds.

4948. That is not fair; the rough contact bed takes the place of the septic tank?

4949. (*Professor Foster.*) You are counting your septic tank?—Yes. In my own mind I have come to the conclusion that no scheme will be adequate that does not preliminarily treat the sewage for a very obvious reason.

4950. (*Major-General Carey.*) Whether it is domestic or not?—For a very obvious reason.

4951. (*Professor Foster.*) What do you mean by "previously treated"?—You must first of all retain it in some vessel in order to get an average sample.

4952. (*Sir Richard Thorne.*) That is your septic tank?—Yes.

4953. (*Professor Foster.*) You do not mean treated chemically?—I do not mean treated chemically. For any system of sewage treatment to be perfect you must have as nearly as possible a perfectly average sample to deal with. You do not want to have to deal during one hour of the day with sewage at 2 and at the next hour of the day sewage at 0 2 albuminoid ammonia.

4954. Why not?—Because no filter can deal with it. Just as analyses are vitiated by the way in which the

Mr. C. J. Whittaker. 21 March 1899.

samples are taken, so I believe a filter will deal with it according as the sample is taken. The chief benefit besides the decomposition that takes place in that open septic tank is that from the Leeds sewage will pass into that tank a sample of all the sewage that comes down during every hour of the day, and in that septic tank you will have an absolutely average sample of the Leeds sewage.

4955. (*Major-General Carey.*) And certain portions of it may counteract and neutralise others?—Certain portions may counteract and neutralise others. Sometimes you have strongly acid sewage coming down, and others strongly alkaline.

4956. (*Professor Ramsay.*) I think I noticed some sort of hint in the opening of your evidence in which you suggested that such tanks need not be near the sewage works at all?—They can be miles away for the matter of that. My notion of a perfect sewage works is down the valley, somewhere out of the way, to run the sewage down so as to hold a week's supply. In doing that you would then get a much better average—that is, you would get wet and dry weathers' mixed together, instead of, as now, if you have a few days' dry weather you have the sewage as strong as possible. Why should you not have an immense reservoir for sewage the same as an immense reservoir to supply a town with water?

4957. (*Colonel Harding.*) You are not afraid of any smell arising from a very large septic tank?—Not the slightest. I think the smell from pressed sludge is far more excruciating.

NINETEENTH DAY.

Wednesday, 20th June, 1900.

PRESENT:

The EARL OF IDDESLEIGH (*Chairman, presiding*).

Sir MICHAEL FOSTER, K.C.B., F.R.S., M.P.
Professor WILLIAM RAMSAY, F.R.S.
Maj.-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.
Mr. WILLIAM HENRY POWER, F.R.S.

Mr. F. J. WILLIS, *Secretary.*

Mr. T. COSHAM, called in; and Examined.

Mr. T. Cosham. 20 June 1900.

DESCRIPTION OF THE "COSHAM" PATENT PRECIPITATING TANKS.

The object of the invention is to construct improved precipitating tanks, which will afford a ready and accessible means of precipitating sewage, after it has been treated with a chemical process, so that the effluent may be discharged bright, clear, and free from smell.

The invention consists of a combination of chambers, arranged in a group, all enclosed in a wall of cylindrical, polygonal, rectangular, or other suitable external form, and preferably formed of cement, concrete, or Staffordshire blue bricks.

The tanks are specially designed to intercept the floating impurities in sewage by means of passing it from one chamber to another through specially-designed flues, or traps. The shielded passages, or flues, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k* (see drawing), effectually prevent the flocculent matter escaping previous to its settling, thus taking only the clearest fluids from one chamber to the next. The floating impurities being collected on the surface of each division, particularly in chambers Nos. 1, 2, and 3, this certainly prevents it escaping on to prepared filters on land for final purification.

Appendix No. 21.

The circular tank is specially adapted to the treatment of sewage in districts where the contour of the land will not permit the precipitated sludge to be conveyed by gravitation on to land.

The sewage to be treated is carried, after being subjected to the precipitating action of chemicals, to No. 1 chamber; it then flows through what is termed a flocculent chamber, *c*, rectangular in shape, into No. 2, thence into Nos. 3, 4, 5, 6, 7, 8, and 9, through the various flocculent flues, *d*, *e*, *f*, *g*, *h*, *i*, *j*, provided in each respectively. The greatest proportion of the solid matter is precipitated in No. 1 chamber, precipitating less in quantity as it flows through the other chambers, until, when the sewage arrives at No. 9 chamber, very little solid matter is found at the bottom. The flocculent chambers or flues, the very essence of the "Cosham" patent, serves to carry the sewage gently from one chamber to another, without distrubing the solid matter at the bottom, and taking up the clarified effluent and suspended matters, which latter collects upon the surface, not remaining in suspension. The effluent, as it runs out of No. 9 chamber through flue *k*, is clear, and contains but little suspended matter.

The precipitate in the centre chamber of the tank is removed by means of a syphon and penstock or chain pump. The lowering of sewage in this chamber by opening the shackle valves, *l*, and the weight of sewage in the other chambers, forces the sludge in them into the centre compartment.

The rectangular tank works upon the same principle as the circular, but is designed to deal with much larger quantities of sewage, and where the contour of the land will allow the sludge to be removed from the bottom of tank by gravitation.

We claim that a far superior effluent can be obtained by this system than by any other, and that, with a considerably less quantity of chemicals and a minimum of labour.

The "Cosham" tanks are at use at the following sewage works, and have been in use for the number of years indicated by the number against the name of the place:—

Awsworth, Notts	50,000 gallons	Constructed —
Broom Park, Durham	15,000 ,,	,, 1897
Barnby Manor, Notts (residence of F. Platt, Esq.).	——	— 1894
Brancepeth (Hall) Durham	50,000 galls. (about)	Constructed 1898
New Cresswell, Notts	50,000 ,,	,, ,,
East Howle, Durham	15,000 ,,	,, 1897
Ferry Hill, Durham	10,000 ,,	,, ,,
Foleshill, Warwickshire	20,000 ,,	,, 1896
Hillstown, Derbyshire	20,000 ,,	,, 1897-8
Kimberley, Notts	250,000 ,,	Converted 1896
Kingston Dairy Farm, W. Kegworth.	10,000 ,,	Constructed 1898
Nuneaton, Warwickshire	500,000 ,,	Converted 1895
Oadby, Leicestershire	20,000 ,,	Constructed 1899
Pleasley, Derbyshire	25,000 ,,	,, 1898
Ruddington, Notts	50,000 ,,	,, 1899
Rothes, N. B.	100,000 ,,	,, 1898
Roade, Northamptonshire	20,000 ,,	,, 1899
Shirebrook, Derbyshire	150,000 ,,	,, 1898
Sedgefield, Durham	10,000 ,,	,, 1897
Trimtion, Durham	150,000 ,,	,, 1898
Tibself, Derby	50,000 ,,	,, 1897
West Cornforth, Durham	50,000 ,,	,, 1898
Waterhouses, Durham	10,000 ,,	,, 1899
Whitehouses (Hall) Lancs.	10,000 ,,	,, ,,
Woolathorpe (Duke of Rutland's Estate).	10,000 ,,	,, 1897
Kibworth, Leicestershire	40,000 ,,	,, 1900

4959. (*Chairman.*) You are, I believe, Mr. Cosham, representing the Natural Purification Company?—I am.

4959. We are much obliged to you for your statement, which we have all read with interest, and which will be placed upon the minutes. I should like to ask you where you would wish us to examine your process?—At Nuneaton, my Lord; there are three tanks there, where they are treating three-parts of the sewage. Part of this is bacterial treatment.

Mr. T. Cosham.

20 June 1900.

4960. We are really much obliged to you, and we will not trouble you further at this stage.

Mr. A. P. Hope, F.C.S., called in; and Examined.

Mr. A. P. Hope, F.C.S.

(1) Our Invention.

In describing the invention we will explain the process as carried out at Hanley, Staffordshire. The sewage arrives at the outfall works, situated one mile from the town, and runs by gravitation into three storage tanks, the capacity of which is about four million gallons. From these it is lifted twelve feet by centrifugal pumps into a channel, where the precipitants are added, viz., seven grains of lime and three grains of protochloride of iron to the gallon (this latter preparation is obtained by evaporating to crystals the bath liquor, in which the rough particles of iron have been dissolved off the plates before being made into galvanised iron).

The sewage then passes into five precipitating tanks (two million gallons capacity) by the continual flow-through method. The resulting effluent is then passed through what are called Bacillite disinfecting batteries, of which there are four, at the rate of four thousand gallons per minute, viz., one thousand gallons per minute through each.

These batteries are chambers 4 feet by 3 feet in area and 3 feet deep, containing perforated pipes, from which steam saturated with carbolic acid permeates the whole of the effluent as it passes through, giving it the appearance of being boiled, although in reality it only raises the temperature 2 per cent. This disinfecting steam is connected with a coke oven, from which it draws by an induced current the carbolic acid gas fumes from the red-hot coke. This latter gas is for neutralising any alkalinity of the effluent, as the object in using it is economy in precipitating, in being able to use more lime and less iron.

The effluent then runs over a portion of land, and from thence into the river Trent, but the Hanley Corporation intend to erect filters, which we recommend, viz., 3 feet of small assorted coke at the rate of a 1,000 gallons per square yard per day. A small filter is at work close to the batteries.

This disinfecting process was invented by our acting manager, Mr. A. P. Hope, F.C.S., M.P.S., and its essential benefits are that large quantities of sewage can be disinfected at a very small cost, three pints of carbolic acid being sufficient to sterilise one million gallons of sewage, the fact of using steam as a vehicle for introducing the germicide, the power of the carbolic acid is increased over 200 per cent.

(2) Advantages Claimed.

That at a minimum of cost all pathogenic germs in sewage are destroyed, and in conjunction with precipitation and filtration an innocuous effluent obtained. We consider this very essential where the sewage from towns runs into rivers from which water is abstracted for drinking purposes.

(3) Grounds of Support of Claim.

These can be exemplified by an inspection of the sewage works at Hanley, Staffs., where the quantity treated is four million gallons per day; and also at King's Norton, near Birmingham, where the amount is four hundred thousand gallons per day, both to the entire satisfaction of the respective authorities, who have renewed their contracts. Reports from eminent experts support our claim and this evidence.

(4) Cost of our Process.

The initial cost of the four batteries at Hanley was about £80.

The Working Cost.—The charge made by the Bacillite Syndicate for sterilisation by this process is four shillings and threepence (4s. 3d.) per million gallons of sewage, this syndicate finding the germicide. This is quite apart from precipitation and filtration undertaken by the authorities.

The places where this process is at work have been mentioned above, viz., Hanley, Staffs., for over three years, and King's Norton, near Birmingham, for four years.

4961. (*Chairman.*) You are Mr. Hope, and you come before us representing the "Bacillite" Sewage Purification Process?—Yes.

4962. The Commission are very much obliged to you for your statement, which we all read with interest, and which will be placed upon our minutes. We do not propose to ask you much now, because we understand that you invite us to examine for ourselves the result of your system?—That is so, my Lord.

4963. Well, we should be very happy to do that, and we should be glad to know where you wish us to come?—Well, we should prefer King's Heath, because we have a laboratory there, properly fitted, and if you will favour us with an investigation we should prefer to have it at King's Heath.

4964. (*Colonel Harding.*) You say here King's Norton; is it the same place?—Well, it is King's Heath, just outside King's Norton.

4965. And it is near King's Norton?—Yes, about six miles outside Birmingham. Visitors get out at Lifford Station.

4966. (*Chairman.*) There is one thing I want to ask you. You say your system destroys all pathogenic germs. Now, do you also say that it destroys all germs?—No, it does not destroy all germs, but it destroys all the pathogenic germs.

4967. Well, how do you know that; have you made a great number of analyses?—Yes, we have made a great number of analyses, but personally I go more by chloride—by the keeping of the effluents, and, of course, also by the analyses. What I find, my Lord, is that the pathogenic germs are destroyed so much quicker than the others.

4968. (*Sir Michael Foster.*) Could you state what germs it does not destroy—I mean, give any particular species which it does not destroy?—No, I cannot tell you that.

4969. By analysis do you mean bacteriological analysis or a chemical analysis?—Well, we have both.

4970. (Mr. *Power.*) Does it destroy the spores of any germs as well as the bacteria themselves?—Yes, it destroys all the spores; we consider it does.

4971. (*Sir Michael Foster.*) Do you know whether it destroys bacillus enteriditis sporogenes? Has that been attended to in your bacterialogical analyses?—Well, we can only conclude that by the effluents and their keeping properties; there cannot be any pathogenic life left in the effluents.

4972. (*Professor Ramsay.*) What do you do with your sludge?—We press it.

4973. And what becomes of it ultimately?—It is thrown out on the land—the pressed sludge.

4974. (*Sir Michael Foster.*) By pathogenic are you meaning putrescing organisms?—Yes, putrefactive germs.

4975. Because pathogenic germs means germs capable of giving rise to disease?—Yes, well I mean to include all putrefactive germs.

4976. That is to say your effluent does not putrefy; that is what you mean by destroying all pathogenic germs?—Yes, it does not putrefy even when it is not filtered; it will keep.

4977. (*Professor Ramsay.*) You state at the foot of page four of your large pamphlet—this one—that it is next to impossible to produce nitrification with a manufacturing town sewage. Is that based on experiments, or on opinion, or what?—Well that is rather an old pamphlet. I do not adhere to that now.

4978. (*Colonel Harding.*) On what scale is the work done at King's Norton?—About half a million gallons a day.

4979. And is your estimate for sterilising 4s. 3d. per million gallons based on that?—No, we charge 4s. 3d. at Hanley per million. We have four million gallons per day there, but at King's Heath where we have had the contract a few years we charge more; it comes in all about 5s. 6d.

(*Chairman.*) Thank you, Mr. Hope, I think we need not detain you any longer.

Mr. H. B. Jagger, called in; and Examined.

Mr. H. B. Jagger.

20 June 1900.

In reply to your request for particulars of our sewage patents, I beg to say as follows:—

The patents are, No. 9312, 1888, granted to Benjamin Jagger, and No. 5753, 1889, granted to Benjamin Jagger, Henry Bateson Jagger and Arthur Turley.

They cover the right to use carbonised refuse in the manner therein described, for the purification of sewage.

The special features of the "Jagger" system of sewage purification consist in making the town's refuse purify the towns sewage, or, in other words, using one nuisance to abate another. That this is possible, it is only necessary to point out that all towns' (ashpit) refuse contains a large percentage of animal and vegetable matter, in the shape of garbage, old boots, rags, bones, paper, wood straws, &c., &c., to carbonise which is to convert it into charcoal, and thus, not only is a cheap and efficient (there is no better filtering medium than charcoal, but it is too expensive to buy) filtering medium obtained, but the enormous first and annual cost (where destructors and such like methods of disposing of refuse are used) of disposing of the refuse is saved.

Briefly, the process is as follows:—

The refuse is deposited in specially-constructed carbonizers, and brought to a red heat, so that, no matter how foul the material may be, it is thoroughly purified and rendered not only innocuous but utilizable as follows:

It is scraped into four grades, the second, third and fourth, sizes consisting mostly of small, medium and large cinders are used in two ways, viz.:—

1st. As preliminary filters by means of which the sewage is deprived of the bulk of its suspended matter.

2nd. As the under layer of filter beds, supporting on top one of the first screenings, being the carbon powder or filtering medium on to the surface of which the clarified sewage is passed, issuing therefrom a clean and inodorous effluent. The filters are capable of dealing with every description of polluted waters, domestic or factory.

The effluent, undiluted, is capable of sustaining fish life. An analysis by Dr. Frankland (Analyst to the Local Government Board), of the effluent obtained by our process from a very bad sewage, that of Halifax, where, in addition to the domestic sewage there is a large volume of "Dye" and other manufacturing pollutions, shows that the whole of the suspended matter and 60% of the soluble organic matter, had been removed.

An analysis by W. Naylor, Esq., F.C.S., &c. (the inspector to the Ribble Joint Committee), of the affluent from our filters at Baildon, taken by himself, shows a removal of 62½% of the albuminoid ammonia.

An analysis by J. T. Ainslie Walker, Esq., F.C.S., of the effluent taken from our filters at Baildon shows the purifications effected in the case of the albuminoid ammonia to be 60·15%. All these results were obtained by single filtration only, but when extreme purity of effluent is desirable and the "fall" will allow, it can be filtered a second or even a third time with no additional cost save the first one of laying down the filters, for the filtering medium costs less than nothing if an allowance is made for the cost of disposing of the refuse.

The impurities in the sewage are arrested either in the preliminary filters, or on the surface of the filter beds, and when the former become choked they are allowed to drain and the contents re-carbonized, and the material again available; when the filters become choked the bed is allowed to drain, the impurities deposited thereon scraped off and, after resting awhile, a fresh layer of carbon powder is laid on and there is practically a new filter ready for use.

The "scrapings" are in a comparatively dry and portable condition, and can either be used for manurial purposes (at Baildon they get 4*s.* a load for it), or they can be re-carbonised and used over again.

That the process is a simple one, it is only necessary to point out that no scientific or even skilled attention is necessary; an ordinary intelligent labourer being quite capable of managing the works.

That it is sufficient, it is only necessary to draw attention to the analysis previously referred to.

That it is economical, it is only necessary to say that there is nothing to buy, and that wherever there are people making sewage that same people are making the refuse necessary to purify it.

Special points in favour of the Carbonized Refuse System:

No precipitant being used the quantity of solids is not increased, and no sludge is made.

The sludge difficulty is solved by making none, the solids are arrested in the cinder pits, or preliminary filters, and where the cinders are "loaded" they are carbonised to the sludge adhering to them, consisting mostly of animal or vegitable matter is converted into "carbon powder."

Unlike land, these filters do not get water or sewage logged. When the effluent flows from them at a less speed than ten gallons per yard per hour it is an indication that sufficient impurities have been deposited on its surfaces, and it is then removable as before described; this, however, cannot be done with land. Land, when choked or sewage logged—must either be abandoned and more bought, or it must have a long period (two years at least) of rest.

Other filtering mediums must be renewed or cleansed—if renewed there is the cost of it—(the carbonised refuse filtering medium costs nothing)—if cleansed, what becomes of the water used for the cleansing? Is it turned into the tanks again, and a circumlocution process continued *ad infinitum*? Or, as is most probable, is it run direct into the effluent channel or stream?

The filters need only have an average depth of about 2 ft., and so in many instances where "fall" is limited the expenses of pumping can be saved.

As regards first and annual cost the Carbonized Refuse System is less than that of any and every other system. At Baildon the total cost of the works (exclusive of the site) for a population of 5,000, was under 1,500*l.*, whilst the annual cost is the wages of one man, who has only to put in about half his time.

Seeing that the material we use costs less than nothing—and this is not a paradox because we utilise what otherwise costs money to dispose of—there is no necessity to use it sparingly, whereas if a chemical precipitant is used, or anything costing money, there is always a temptation to economise, to use less when nobody is expected to examine the effluent, and to use more than could be afforded when the inspector is inspecting or a "show" is being made.

The Carbonized Refuse System has been at work at Baildon night and day since 1893, and has continuously produced a satisfactory effluent.

Attention is directed to the analysis and testimonials as per following pages.

I have confined my remarks to what may be called the practical and economical features of the system, and, these being assured, the financial advantages follow as a matter of course.

What has been and is being done at Baildon can be repeated *ad infinitum*—that there is money in the scheme goes without saying, and as an indication of the possibilities I may say that we entered into an agreement with the Baildon Local Board to "run the works" for 80*l.* a year, we paid a man 1*l.* a week (and he was unemployed half his time) so we made 30*l.* profit on 50*l.* The Local Board, however, soon, after nine months working, terminated that arrangement by "running the works" themselves.

Baildon is the only place where the system is in operation, because of the cast-iron rule of the Local Government Board requiring all effluents to be passed through land before being finally discharged into the rivers, whereas by our process land filtration is not needed, local authorities are not prepared to adopt dual systems, and as they must have the land process they do not need ours.

ANALYSIS of Sewage and Effluent by Dr. FRANKLAND, Analyst to the Local Government Board.

In Parts per 100,000.	Sewage.	Effluent.
In Suspension:		
Mineral Matter	30·00	–
Organic „	14·72	–
In Solution:		
Total Solids, in Solution	71·30	165·00
Organic Carbon	3·625	1·341
„ Nitrogen	·943	·427
Ammonia	8·20	·65
Nitrogen as nitrites & nitrates	–	1·364
Total Combined Nitrogen	7·696	2·326
Chlorine	12·2	7·2

The excess of solids in solution in the effluent over that found in the sewage is owing to its having dissolved out soluble portions of the filtering media, but this is of no hygienic consequence so long as the filtering medium (the town's refuse) is perfectly carbonized.

Irrigation does not change the amount of chlorine.

Note.—The sewage sample was taken from the outfall of the Halifax Corporation, at the entrance to, and the effluent at the exit from, the filter bed constructed to the order of Messrs. Jagger. They were taken by order of Colonel Ducat, R.E., Inspector of the Local Government Board, who held the "enquiry" at Baildon, by the employées of the Halifax Corporation in the presence of Mr. J. H. Ward, Clerk to the Baildon Local Board, and Mr. H. B. Jagger.

ANALYSIS of Sewage and Effluent taken at the Sewage Purification Works (Carbonized Refuse System), belonging to the Baildon Local Board, by J. T. AINSLIE WALKER, Esq., F.C.S.

In Parts per 100,000.	Sewage.	Effluent.
Total Solids, (in Suspension and Solution)		
Mineral Matter	216·00	102·80
Organic „	116·00	18·40
In Solution:		
Albuminoid Ammonia	7·40	0·18
Free „	3·40	2·90
Chlorine	4·97	9·94
Alkalinity	29·70	19·80

ANALYSIS of Carbon Powder, the material forming the top layer of the Filter Beds at Baildon, and obtained by Carbonizing the Town's (Ashpit) Refuse, by J. T. AINSLIE WALKER, Esq., F.C.S.

In Parts per 100,000.	Sewage.	Effluent.
Carbon	12·50	—
Oxide of Iron Alumina	15·52	—
Carbonate of lime	10·60	—
Phosphate of „	3·00	—
Carbonate of Magnesia	3·14	—
Alkaline Salts	3·00	—
Insoluble Matter, Sand, etc.	47·70	—
Moisture	4·71	100·17

It will be obvious that the above material must be far superior to any soil on any sewage farm anywhere.

Filters composed of it make practically a system of artificial land filtration capable of constant renewal (which you cannot do with real land), and which will work in all sorts of weather, frost and rain included, and this cannot be claimed for irrigation areas.

Further ANALYSIS by the aforesaid J. T. AINSLIE WALKER, Esq.

"The results of my Analysis of the sealed samples of "Baildon sewage and effluent received from Mr. Heap "on the 4th instant, are entirely satisfactory."

"As you will observe, the purification effected b "your excellent medium, in the case of the albuminoid "ammonia, is 60·15 per cent."

ANALYSIS by W. NAYLOR, Esq., F.C.S., A.M.I.C.E., Inspector to the Ribble Joint Committee.

"As promised, I enclose you the estimations of albu- "minoid ammonia in the samples I took at Baildon on "the 17th January 1894, which are as follows :—

"Parts per 100,000—
"Raw Sewage ·345.
"Tank Effluent ·330.
"Filter Bed do. ·150.

This shows a removal of over 62 per cent.

Letter from Baildon Local Board of Health.
September 22nd, 1893.

With reference to your enquiry as to how the Board find your system of sewage purification to work, I am directed to state that the plant as arranged by your engineers leaves nothing to be desired.

The filters have worked admirably from the beginning, and after a week's use are as fresh as ever when a skinning of carbon powder has been taken off the top, and renewed. The effluent is always clear, sparkling, and odourless, however dense the sewage.

Mr. H. B. Jagger. 20 June 1900.

The carbonizer has not been out since it was lit, being kept smouldering with ashpit refuse and producing sufficient carbon for the filters, and at the same time disposing of the surplus refuse.

The more we see of it the more we are convinced that the system should be universally adopted on account of the small cost and not requiring a large area of land.

Yours truly,
(Signed) J. H. WARD,
Clerk.

Further letter from the Baildon Local Board of Health
November 16th, 1894.

The Carbonized Refuse System of Sewage Disposal has now been working here for the last 20 months and still gives entire satisfaction.

The effluent is as good to-day as it was the first week of trial.

My Board intend to lay a sewer to another hamlet in the township and bring the same into connection with the outfall works referred to.

I am to say that in the opinion of this Board Messrs. Jagger's process solves the two most important problems for Sanitary Authorities: viz.:—Disposal of Ashpit Refuse and Sewage Purification, at a very low cost.

Yours truly,
(Signed) J. H. WARD,
Clerk.

Further letter from Baildon Urban District Council,
January 4th, 1897.

The Chairman has handed me your letter to him of the 25th November last at your request. I am desired by the Council to state on their behalf that the works constructed 3½ years ago for the disposal of Ashpit Refuse and Domestic Sewage Purification, have given entire satisfaction and is worked at little cost.

Yours faithfully,
(Signed) H. R. HUGGINS,
Clerk.

4980. (*Chairman.*) You are Mr. Jagger?—Yes, my Lord.

4981. And you represent the Carbonised Refuse System of Sewage Purification?—Yes, one of the patentees; in fact, the only one now, because my father has died since the patent—well two years ago—since the patent was taken out.

4982. The Commission are very much obliged to you for your statement, which we have all read with interest and which will be placed upon our minutes. We do not propose to ask you much now because we understand that you invite us to examine for ourselves the results of your system?—Yes, at Baildon.

4983. Yes, we shall be very happy to do so; where did you say you would like us to examine them?—At Baildon, near Bradford.

4984. (*Colonel Harding.*) Your process is one of mechanical filtration of the solids in suspension so as to keep such solids on the surface of their own material?—That is so.

4985. Then do you suggest that it is practicable on a large scale—say with filters of 20 acres area—to take out the material and to burn it afresh and to restore it so as to go on working?—That is our experience. The works at Baildon have been working since 1892 I think it is now, and they have carbonised and re-carbonised the material time after time. I was over there at Christmas last, and I believe only two or three of the filters have had to be re-laid. I should like to explain a little further.

4986. Just answer my questions; I do not think the Chairman would desire you to go over the ground again; your answer is that it is practicable on a large scale?—It is practicable, yes.

4987. To re-burn the material and use it again?—To re-burn the material and use it again, only it is not necessary to do so because it can be used for manurial purposes, because we are always having a supply coming forward wherever there are people making

Mr. H. B. Jagger.
20 June 1900.

sewage. Our contention is this, that wherever there are people making sewage that requires to be purified, those same people are making the refuse which we carbonise to do it with.

4988. Your system is only at work at Baildon?—We have had it adopted by many other Local Authorities, but the Local Government Board have stood in the way of it; they insist upon having an acre of land for every thousand population, whereas we only require an acre of land for every 20,000, and of course if they insist upon the land being obtained they do not want our filters.

4989. (*Major General Carey.*) You know that the District Council have been informed by the Local Government Board that the effluent was not satisfactory according to the analysis of their own analyst?—I was informed of that, but it was on account of carelessness in management; it was not on account of the system. After it had been working five years we had a letter from the District Council informing us that it was working entirely satisfactorily.

4990. (*Chairman.*) I do not know that we have anything more to ask; I do not know that there is anything more that you would wish to say?—There is one little matter which I should like to explain, perhaps; it ought to have been added to my statement. I thought I should have had an opportunity of giving further evidence than what I have already sent in, because this was done rather hurriedly; and it is this, that we have since ascertained—since the patents were taken out, we claim that by converting the animal and vegetable matter in the town's refuse and carbonising it and converting it into charcoal, that it was that entirely that did the work, but we found after a period of rest that the filters regained their efficiency, but that was not the result of recarbonising, it was the result of aeration, and since then, of course, the bacterial process has come very largely to the front, and I have examined that very minutely, and I think that the construction of their filters is exactly the same as our own, and that the material that we use is practically the same as the material that they use. They merely use material for aerating purposes, and we get it out of the town's refuse, so that it has occurred to us now that after all it may not be purely the carbon. The carbon does the decolourising certainly, because at Halifax we had there sewage highly charged with dyed waters and we have brought them out perfectly clear, but it seems to me that our filters are practically the bacterial system as well.

4991. (*Professor Ramsay.*) Do you not find disintegration in your filters?—Only during the first six months, and then they get perfectly settled. When they get perfectly settled we have nothing whatever to do except just to scrape the top off which contains the impurities left after the preliminary screening, and then if they are left to aerate we have them scratched up with the rake, and as much relaid as we take off, and the filters are practically new, and that is our experience in long working.

4992. (*Major-General Carey.*) How long do you rest the filter?—Well, we did give them three days' working and about a day and a half to two days' rest, but we give them as much rest as the sewage will allow us.

4993. (*Professor Ramsay.*) But when this re-making and raking takes place how long rest do you give then?—About a day and a half.

4994. (*Major-General Carey.*) What do you do when the filter you have been working is at rest? You have not so large an area of filters as to use others, have you?—Well, we filter at the rate taking three days of 12 gallons per yard per hour, so that it is only a matter of calculation. At Baildon they have ample filters there where they have only eight filter beds. Yes, it is 12 gallons per yard per hour, and each filter has about 100 superficial area, so that for 3,000,000 gallons we should require 36 filters. That would be an acre.

4995. (*Professor Ramsay.*) And the depth of the filter?—The depth of the filter average 2 feet—the depth of the filtering material.

4996. That is what I mean?—I think I can give you the exact figures.

4997. Then, if I understand rightly, you never recalcine the whole of a filter at once?—No, we have never had the necessity to do so, because at Baildon the farmers will cart it all away, and will give 2s. 6d. a load for it, so there is no necessity to carbonise, because to carbonise it is to destroy the manurial properties, which is not what under those circumstances we desire to do. There is plenty of refuse at the farms coming down you have to dispose of. We take it and dispose of it. I think I fully explained in my evidence we have a contract with the Baildon Local Board, it was then, by which it was arranged that we should do it for £80 a year. Well, we had not full employment for one man, and at the end of six months they cancelled that agreement and did it themselves. We were making £30 a year out of it, and we gave the scrapings from the filter beds as manure to the farmers, but I understand the Baildon District Council are able to dispose of it. I had a letter to that effect some years back now—at 2s. 6d. a load. The construction of the filter beds is as follows: There is 2 inches of clinker and large cinders left after the third riddling. Then we have 3 inches which has passed through a three-quarter inch mesh, 3 inches that has passed through a three-eighths mesh, and 4 inches on the surface—4 to 6 inches. We lay six to allow for settling, but we allow an average of 4 inches of the carbonised powder. That is everything. We pass it through a three-sixteenths riddle, and then we have head of sewage 6 inches on top of that, and then we have a fall of 6 inches, so that at the top end the filter is 18 inches deep and at the bottom 2 feet deep.

4998. Does it not require a great preliminary screening? Do you not find the top of the filter block pretty freely, it is so fine?—No, but at first it runs through rather too freely, that is why we lay 6 inches at the top. It must not pass too freely. If it passes too freely it has not time to get filtered. We took very careful gauging of the flow, and the average works out exactly at 12 gallons per yard per hour the superficial yard on three days' working. Of course, it passed at about three times that speed the first day, about half that the second day, and about half that again the third day, because the imparities settling on the surface form a skin and choke it.

(*Chairman.*) Thank you. Then I do not think we have anything else to ask.

Mr. Frederick Wallis Stoddart, called in; and Examined.

Mr. F. W. Stoddart.

My evidence relates entirely to the so-called filtration of tank effluent, that is the oxidation of the dissolved constituents of sewage from which the bulk of the suspended solid matter has been removed by accepted methods of tank treatment.

The improved means of effecting this change may be conveniently divided into two parts, namely, the distributor, by which the comminution of the sewage is brought about, and the modified filter by which the sewage already minutely subdivided is exposed in the thinnest possible films to comparatively large volumes of air throughout the whole depth of the filtering medium.

The distributor, a model of which is exhibited, consists of a gutter-shaped vessel, provided along its underside with a series of vertical points. The tank effluent passes along the gutter, overflows its margins, and on reaching the nearest point drops from it upon the surface of the filter.

In practice the distributors are formed from a corrugated sheet of special design, slots being punched at intervals to allow the tank effluent to reach the under surface.

This form of distributor requires only sufficient head to allow the tank effluent to find its way to the under surface—that is about an inch—and is perfectly indifferent to climatic changes, discharge of sludge from the tank, and like accidents; and has never been interrupted in its action from any cause of the kind, although from reasons connected with the filter it is well to keep the distributor fairly free from deposited solids.

Having no moving parts, and no fine apertures there is nothing in the distributor capable of being disarranged, or thrown out of action.

The modifications I suggest in filter construction are three in number and are intended to maintain the fine state of division of the liquid, and to obtain the maximum exposure to air.

To this end the filtering medium, the composition of which is immaterial, is of so coarse a grade—two to three

inches—as to preclude the possibility of coalesence of the liquid adhering to adjacent particles.

Retaining walls are dispensed with altogether, there being no bulk of liquid to hold up; and the final effluent is allowed to drain away into a circular collecting channel outside the filter, without the intervention of pipes or channels of any kind.

By the combination of the distributor with the improved filter, the liquid is maintained during the whole of its stay in the filter in so fine a state of subdivision as to appear merely as a moistening of the surfaces of the particles of medium, and the conditions therefore are exceedingly favourable to oxidation, whilst there is no check either to the action of the oxidising microbes, or to the free supply of oxygen such as is inseparable from the mode of action of the intermittent filter.

I claim that a filter constructed on these lines and six feet in depth will automatically and continuously purify upwards of 1,000 gallons of average tank effluent per day for an unlimited time, the oxidation being sufficiently thorough to render subsequent putrefactive changes impossible. The percentage of purification calculated from the reduction in albuminoid ammonia or in oxygen absorbed is about seventy per cent., the proportion of nitric nitrogen formed is about two to three parts per 100,000, and the quantity of dissolved oxygen is considerable.

A special feature of this filter is that the amount of purification is directly proportional to the cubic capacity, so that area may be diminished in proportion to increased depth where much fall is available.

Practical advantages arising out of the special construction are marked reduction in cost of erection and in labour, and the ease with which a filter may be extended or altered in dimensions.

The proofs upon which I rely to substantiate my claim as to the efficiency of the filter are of three kinds:—a priori considerations arising out of common knowledge as to the action of sewage filters generally, the results obtained with laboratory apparatus, and those obtained by the application of the same principles on the working scale.

It has been generally agreed since the First Report of the Royal Commission on Rivers Pollution that the sewage filter is essentially an oxidising instrument, the source of the required oxygen being the air. If this be so it follows that the intermittent filter, as devised by the Royal Commissioners, and still more the type in common use at the present day, must be more or less inefficent because during a considerable part of the cycle of operations the liquid to be oxidised lies in bulk and by no means in intimate contact with air.

It was this consideration which led me to the construction of a continuous filter of small dimensions by means of which it was clearly demonstrated that not only is a great waste of time involved in pouring liquid in bulk on an oxidising filter, but that the oxidising microbes are greatly debilitated by submergence in a fluid devoid of oxygen, and that aeration of such portions of the filter as may not be waterlogged is much interfered with by the seal formed by even a slight layer of liquid in any part of the filter.

The period of rest insisted upon in connection with the intermittent filter is therefore only an attempt to remedy the mischief caused by overdosing the filter in the preceding stage.

The soundness of these views is finally proved by the success that has attended their application upon a larger scale.

Experimental filters at Horfield have been running continuously for many months, one in particular one square yard in area having been at work without interruption since October 6th, 1899. Here the effluent from a precipitation plant is treated, but owing to its very exceptional strength the quantity has to be reduced in dry weather to about 500 gallons per square yard daily.

A larger filter—30 square yards in area—was erected in October 1899 to deal with the effluent from a septic tank into which the sewage of Knowle, a suburb of Bristol, is drained. This filter has been running quite continuously since January 30th, with uniform success, though occasionally nearly 10,000 gallons has passed through each square yard daily, and the average dry weather flow is about 1,300 gallons per yard.

As to cost of this form of filter whilst of course the distributor increases the expense of erection, this increase is counterbalanced by the simplification in construction and especially by the absence of walls and foundations, so that the prime cost exceeds by little if at all that of the usual type of intermittent filter. As however the improved filter does five times the work, it is in reality much cheaper, and in addition to this saving in initial cost there is to be considered the practical abolition of working expenses.

I calculate, therefore, that the substitution of the continuous for the intermittent filter represents a saving of not less than 75 to 80 per cent., ensures the production of a better effluent of uniform character, and reduces to a minimum the risk of stoppage or interruption of the process of filtration.

ANALYSES OF SEWAGE EFFLUENTS PRODUCED BY STODDART'S PATENT FILTER.

RESULTS EXPRESSED IN GRAINS PER GALLON.

	Exceptionally Strong Sewage, Oct. 20th, 1899.			Dry Weather Flow, Oct. 3rd, 1899.			Wet Weather Flow Oct. 6th, 1899.
	Sewage.	Tank Effluent.	Filtrate.	Sewage.	Tank Effluent.	Filtrate.	Filtrate.
Saline Ammonia	35·63	10·08	6·3	6·832	2·698	1·295	·14
Albuminoid Ammonia	9·45	·77	·26	·907	·319	·090	·085
Nitrogen as Nitrates and Nitrites	none	none	1·50	none	none	1·80	1·27
Oxygen absorbed: 15 mins. at 80° F.	—	—	—	2·38	·616	·245	—
„ „ 4 hrs. „	23·10	3·50	1·47	5·39	1·218	·490	—
Suspended Solids	—	—	—	21·0	3·2	none	none
Appearance	opaque	opalescent	Turbid, with clinker debris, rapidly clears.	opaque	opalescent	brilliant	brilliant
Odour	sewage	sewage	Slight, earthy	sewage	sewage	Slight earthy odour, not suggestive of Sewage or unpleasant.	
Daily rate of flow: gallons per sq. yard			576			1,416	1,800
„ per acre			2,787,840			6,853,000	8,712,000

Mr. F. W. Stoddart.

20 June 1900.

4999. (*Chairman.*) You are Mr. Wallis Stoddart?—Frederick Wallis Stoddart.

5000. You are county analyst?—City analyst for Bristol.

5001. Well, we are much obliged to you for the statement which you have given us, and which we have all read, and it shall be placed upon our minutes. I do not know really that we should want to ask you very much now, because I suppose you would invite us to examine the result of your distributor?—I should like to do so, my Lord.

5002. And where would you like us to examine it?—The most complete installation at the present time is at Knowle, a suburb of Bristol, but I have been making some alterations there in one or two directions—I shall be pleased to explain them, if you desire it—and it will be in working order again next week, but any time after that I think it might be examined. When I say a complete installation, I mean including both tank and filter complete. I am treating the sewage of the suburb completely. I think that will be the most suitable place. There is also an experimental filter at Salisbury.

5003. I suppose if we send anyone down we could always get at it?—I will make arrangements that they shall do so. It is the property of the Corporation, of course.

5004. (*Professor Ramsay.*) As regards the separator, is it not very apt to choke? It is a set of gutters, I understand, with holes at the top?—May I show you the model I brought with me for the purpose? I think it would be better than anything verbal.

5005. I think we should like very much to see it?—The tendency to choke is absolutely fatal, I consider, to any kind of perforated apparatus, and, therefore, after waiting some years, I discarded all kinds of perforated apparatus. The tank effluent of sewage does not pass through any kind of perforation; it is an outside flow all the time.

5006. But does this part not clog with the deposit?—There is a certain amount of deposit when brushed out, but we put that back into the bed at Knowle. It is very little. That need only be done at long intervals, and it is only the suspended matter in the tank effluent, which is very small.

5007. You do not think that solid depositing in the gutter forms any objection?—Not in the least. The gutter might be absolutely filled with solid matter, and it still works as if it were empty.

5008. Do you use a certain number of distributors like that, or are they made continuous, like a corrugated roof?—The channels are made a number altogether in the plate. These things are represented in the actual working plan, by castings, which are bolted together. Then those sections are complete; each section is complete in itself, but it can be used in a series or it may be adapted to the shape of the filter-bed.

5009. Do you know Colonel Ducat's apparatus?—I have not seen it.

5010. You know the plan?—Yes.

5011. Is this intended as a filter something of the kind of Colonel Ducat's?—I think so. As I understand it, Colonel Ducat's filter is walled in by drain pipes.

5012. Yes?—That does not affect the matter. The drain pipes in my view are quite unnecessary. It would be an open filter of that character.

5013. Perhaps you know Whittaker's filters?—I think, again——

5014. You may have read of it?—Yes, I have read of it. I have rather avoided seeing any of these things.

5015. My point is really to understand the sort of system to which you wish to apply this system. It is an open filter?—With no possible liquid in it at all.

5016. Trickling over the whole time?—A trickling over continuously.

5017. From top to bottom?—Yes. For the actual disappearance is such that all you see in the filter, if you look into the filter, is a number of moistened lumps of clinker.

5018. Do you propose to give the sewage a septic treatment first or is not that part of your scheme?—A septic treatment.

5019. In a septic tank?—I am quite clear upon this, that it is not profitable to throw any material amount of solid matter upon any kind of filter. Solid matter occurring in crude sewage is far more easily and economically dealt with in some sort of tank, and I do therefore adopt a tank, a tank process. I do not confine myself to a septic tank or precipitation tanks, or what not.

5020. (*Sir Michael Foster.*) You apply your distributor and filter to several previous preparations?—To one of several, yes.

5021. You would apply that to a precipitation process?—I am doing so at Horfield, yes.

5022. (*Mr. Power.*) You would require the sewage to be clarified before you deal with it?—Yes, I treat what is commonly known as a tank effluent, and not a crude sewage.

5023. You do not want suspended matter in it?—I do not want suspended matter; nothing else matters very much except so far as the strength of the liquid treated regulates the amount you can pass through the filter in a given time. I brought a recent analysis just bearing upon that point. This filter at Horfield dealing with exceedingly strong tank effluent cannot take my stock quantity of a thousand gallons per square yard, but I have been experimenting there, and I have been diminishing the quantity to see how far the additional purification becomes manifest, and I had an analysis of a sample of effluent I made last week. It might interest the Commission. The effluent is unnecessarily good—altogether unnecessarily good, and with the exception of some suspended matter to which I did rather wish to call the attention of the Commission—this suspended matter—may I put that before you—there is a certain amount of suspended matter at the bottom of the sample—that is clinker, and is very silicious in character, and is with a little trouble to be entirely coped with (*Showing sample.*) That is some of the same matter simply dried from a sample. (*Showing.*) The destructor clinker invariably used up to the present is of a comparatively soft character owing, no doubt, to the inclusion of a good deal of vegetable matter in the city refuse before it is burned. That breaks down a little; it renders the sample somewhat unsightly, but does not in any way affect its keeping powers or tendency to putrefy.

5024. (*Mr. Power.*) Is this the filtrate?—That is the filtrate. That solid matter in the bottle is not solid matter originally present in sewage at all; that is entirely derived from the clinker.

5025. (*Professor Ramsay.*) The filter itself?—I am probably getting over it by the adoption of a harder clinker.

5026. (*Colonel Harding.*) May I look at this. (*Examining sample.*) Is this the filtrate?—It is the filtrate at a very low rate.

5027. Do I understand you to suggest that these solids are part of the material of the filter?—They are; they are not sewage solids.

5028. What are they?—they are broken down clinker.

5029. (*Sir Michael Foster.*) What is the analysis of them specifically?—Of the solids?

5030. You have analysed this?—Roughly, a great deal of silicon, a great deal of carbon left, and it is very obviously derived from the clinker. Of course, the particles of clinker are naturally coated with an organic growth, and do furnish some organic matter. There is an enormous nitrification in that sample of eight parts per hundred thousand of nitric nitrogen, a condition which is quite unnecessary to reproduce in practice. The tank effluent might be passed at double that rate, and still pass.

5031. Is the sewage that you speak of anything like the one of which you gave an analysis in your statement containing 35 grains per gallon of ammonia?—That is the analysis of a tank effluent and filtrate, only it is a stronger sewage than that.

ANALYSES OF EFFLUENTS.—RESULTS
in parts per 100,000.

	HORFIELD, 29th May 1900.		KNOWLE, 15th June 1900.	
Rate of Flow per day per square yard.	252		2,070	
Rate of Flow per day per acre.	1,200,000		10,000,000	
	Tank.	Filter.	Tank.	Filter.
Saline Ammonia	13·43	1·00	6·00	3·85
Albuminoid Ammonia	1·10	·28* ·18†	·76	·27
Oxygen absorbed, four hours at 80° F.	7·00	1·90	3·49	1·70
Nitrogen as nitrates and nitrites.	None.	7·92	None.	1·31
Chlorine as chlorides	12·10	12·00	10·40	10·20
Appearance and odour	Very turbid: strong sewage odour.	Turbid, but clears rapidly—no odour.	Very turbid: strong sewage odour.	Turbid, but clears rapidly—slight earthy odour.
Purification on Albuminoid Ammonia.	—	75* 84†	—	65
Purification oxygen absorbed.	—	73	—	50

* Including sediment. † Decanted.

5032. (*Professor Ramsay.*) The free ammonia is enormous in amount?—This is enormous—no, about the same, 1·1 albuminoid.

5033. Is it owing to the presence of urine?—Yes, that is due to the fact that the sewage at Horfield is largely produced at barracks, and we get an enormous quantity of urine.

5034. (*Sir Michael Foster*). How much carbon is there in the precipitate?—I cannot tell you how much.

5035. (*Mr. Killick.*) This paper that you hand in with regard to the sewage at Horfield shows the oxygen absorbed 1·90, albuminoid ammonia ·28, and ·18. Do you consider that a satisfactory effluent?—That is a very satisfactory effluent.

5036. And it will not putrefy afterwards?—It will not putrefy afterwards.

5037. Well, you see the standard adopted by Sir Henry Roscoe is for the oxygen absorbed 1·3. This is much worse?—Yes.

5038. Our experience is that this will putrefy?—Subject to correction, I do not think it would. This question of limits is, of course, one which is open to a good deal of discussion. I think if that effluent was produced by sewage at enormous strength, three or four times the strength of ordinary sewage, that although there was a considerable actual residual amount of organic matter, it is unputrescible organic matter. In fact, experience leads me to suppose that just as in the septic tank operation itself, there is a residue which is incapable of further attack by the organisms under one definite series of conditions. What I mean by that is this, that in the septic tank, however long you leave the sewage in the septic tank, there is a nitrogenous organic residue which is permanent, and it seems to me that in the same way the changes, which are quite different in character of course, which go on in the filter, there is a residue which no prolonged treatment will dissipate. And for that reason I think a proportionate reduction in impurities rather than a reduction to an absolute fixed amount is the proper kind of standard to adopt.

5039. (*Mr. Power.*) Have you incubated this filtrate?—This is rather a recent one. I had that incubated, and at the room temperature both in full bottles and partly filled bottles, simply with a view of seeing whether naked eye changes took place, and it has remained perfectly sweet and unaltered. I have not taken the oxygen absorption before and after the test which is adopted in some quarters.

5040. (*Major-General Carey.*) Do you filter the tank effluent passing through the filter?—Yes.

5041. Without any rest?—Without any rest.

5042. Day by day?—Day by day.

5043. And a thousand gallons per yard is your average?—Yes, a thousand gallons per yard is our average. That is under the mark for what I call an average tank effluent. That is tank effluent giving about ·5 parts per hundred thousand of albuminoid ammonia, but the other half of that paper I put in was an attempt to show that by old sewage—the effect of a very much larger quantity of ordinary sewage, but owing to those alterations of which I was speaking just now, only one part of the tank is in use, a part of the capacity of about 12,000 gallons, the daily flow being about 30,000 gallons, and the effect of that is that the tank effluent, when the sample was taken last week, was a good deal stronger than an old tank effluent is when things are working properly, and I did not get as complete a purification as I should have liked, but even with the enormous flow of over 2,000 gallons on the square yard, there was a degree of purification which almost passed muster. I do not wish to say that these things are quite satisfactory, because I do not think that the state of purification is sufficient, but had the tank effluent been of its usual character, I did not know, of course, until I made an analysis, the filtrate would have shown a reduction in the oxygen absorbed of 75 per cent.

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5044. (*Professor Ramsay.*) Might I ask a question unconnected with your process, Mr. Stoddart—from a general analytical point of view as regards your opinion of the oxygen absorbed test and the albuminoid ammonia? When do you think they reveal much as to the real character of an effluent?—Reveal much?

5045. I suppose you get a great number of analyses to do; on what grounds do you base your conclusions?—As regards the satisfactory character of an effluent?

5046. Yes?—Oh, on the proportionate reduction. In these two respects I do include that as having some value, the formation of nitrates, and to some extent the amount of dissolved oxygen. That is a question I have under consideration still. On several occasions this effluent has given dissolved oxygen of about 50 per cent. of the saturation quantity, which is pretty good. But at present my standards for the satisfactory effluent are reduction of the organic matter, as indicated by those two determinations on the crude sewage, reduction in the tank effluent in the crude sewage of 50 per cent., in the filter effluent on the tank effluent of 75 per cent. As regards the nitrates, I think some standard such as 50 per cent. of the total nitrogen remaining in the effluent in the nitric or nitrous form should be insisted upon. I think those together are evidence that the reduction in organic matter is not a matter of dilution, but is truly the result of oxidation.

5047. (*Colonel Harding.*) In using continuous filters distribution is, of course, a great difficulty?—It is *the* difficulty.

5048. And the idea is, of course, to run the sewage in drops equally over the whole area?—Yes.

5049. Now with your distribution you suggest that it is only practicable with sewage from which almost all the solids have been excluded by some previous process?—No, sir, I am afraid that is not a fair deduction from what I said just now.

5050. Well, will you tell us what quantity of solids in suspension you think you can deal with by your distributor?—May I just say first, sir, that the question of solids in suspension is a matter affecting the filter much more than the distributor. It does not affect the distributor at all. The distributor may be completely filled up, and has on several occasions been completely filled up.

5051. We will talk about the distributor for the moment; we will talk about the filter after. With how much solids in suspension can this distributor practically deal? Do you say it can be filled up without interfering with its efficiency? Do you not say that?—I do say that—yes.

5052. That the groove may be filled without interfering with its efficiency?—Precisely.

5053. Why do you not construct them in that way, then? Why do you not have the bottom of them in flat rectangular shape and have the slots coming to the bottom, because clearly in a very short time that condition will come to pass?—No, sir, not in a very short time, as far as my experience goes—certainly not more frequently than once a week. The channels are continually brushed out once a week. I should like to make this clear, if I may, that the presence of solid matter in the distributor does not in the least degree affect the action of the distributor itself. If the channels are filled with solid matter the tank effluent will pass through the gauges and drops into the filter as before,

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but the solid matter begins then to be left in the filter, of course. Although the extreme coarse filter that I use is never clogged thereby, no doubt the oxidising——

5054. Do I understand you the "V" shape that you give to these distributor troughs is for the purpose of keeping back certain solids which you can remove once a week by brushing out?—It was not designed with that idea at all, sir? The intention of the "V" shape trough is to provide a sufficient rigidity to avoid collapsing under the weight of the water. It could not be done with the ordinary corrugated pattern.

5055. You said you did not want those solids in suspension to come on the filter and there was much good being done in these troughs, so that they could be cleaned by brushing and otherwise at the end of the week?—No, sir, I did not mean that quite. I think the place to deal with these solids is in the tank, not in the filter or distributor at all. A small quantity must be dealt with there, but it need not be more than about five parts per hundred thousand of suspended matter in the tank effluent.

5056. We come to this, that you think your distributor is suitable for dealing with sewage containing not more than five parts per hundred thousand solid matter in suspension?—Precisely.

5057. By what previous process can you obtain such reduction? Have you a septic tank?—Yes.

5058. Can you in the case of a septic tank get an effluent with so few solids in suspension as five parts per hundred thousand?—Oh, yes.

5059. No difficulty with that?—No difficulty at all.

5060. You are dealing with domestic sewage? Domestic sewage.

5061. And what is the rate of flow through the septic tank?—Up to the time of commencing these alterations the capacity of the tank was just over 20,000 gallons; the daily flow was about 40,000 or 45,000 gallons.

5062. And even in that case you had not more than 5 grains per 100,000 in suspension coming out?—Constantly we have got that, but one portion of the tank I had to adapt myself to existing circumstances there; one portion of the tank was only 3 feet deep, and on an occasion of exceptional rainfall the sediment in the shallow part of the tank was constantly driven forward. In fact, I had the same difficulty at Exeter. I had some filters there in action for some months, and this is quite satisfactorily avoided by providing proper sludge discharge and preventing the accumulation of sludge in the septic tank beyond a certain depth. That is what I have done at present, and as far as I can see the tanks are now working and they are likely to work satisfactorily, and I think will give me a tank effluent not containing more than five parts.

5063. You suggest, then, this system of troughs is practicable on a large scale—say, from 20 acres?—Oh, certainly; no question about it. I have all practical details now.

5064. The characteristics of your filtration appear to be these: Coarse material, inexpensive construction, construction without retaining walls, and a circular drain to receive the effluent?—As regards the filter, yes.

5065. You are aware that that has been done by others?—Yes.

5066. Then you use coarse material for the purpose of securing oxidation?—Yes, securing the open character of the filter.

5067. But I am surprised to find that you say—is it at Horfield or at Bristol?—that you have passed 10,000 gallons per square yard daily?—Yes, at Knowle, that is. May I just refer to my proof?

5068. That is an occasional condition?—Oh, quite.

5069. But the normal condition, you say, is 1,300 gallons per yard?—1,300 gallons per yard, yes.

5070. And that has been going on for a long time? That was going on from late in December until a few days ago, when I took that sample. This sample was taken on the 15th of June, when half the filter was in action, the other half being involved in the changes I have just been referring to.

5071. Are we to take it that this filter has been working continuously for many months at the rate of 1,300 gallons per yard?—Five months, at least.

5072. And what is the percentage of purification obtained, measured by albuminoid ammonia or by oxygen absorbed?—From 65 to 75 per cent.

5073. 65 per cent.?—From 65 to 75 per cent. reduction upon these two tests.

5074. Reduction upon what? Upon the original sewage or what went on?—Oh, no; upon tank effluent.

5075. What is the speed at which the sewage passes through this coarse bed?—it takes about twenty minutes to pass through the filter.

5076. What is the depth of the filter?—Six feet. All these calculations are based on 6 feet.

5077. How coarse is the material?—Up to the present there has been from half-inch to three-quarters. That is why I am having it altered, in accordance with altered ideas, to very much coarser material. The filter is now being filled with material very much larger. Everything that will pass through a 2-inch screen is excluded.

5078. So that the material is coarser?—Coarser material, yes.

5079. Surely the sewage would pass through very much quicker than 20 minutes?—No, not applied in this way. Poured directly on the filter it is a matter of seconds and purification is *nil*, but it has such a long course to take in passing in this invisible film, indeed, over these particles one to the other.

5080. But 1,300 gallons per square yard—that is a rush?—In 24 hours.

5081. It is a torrent?—In 24 hours?

5082. Yes?—Well, that has been a difficulty with everyone with whom I have been in communication, and everyone who has come to visit the filters has expressed astonishment at the rate, which appears to be nothing like the rate you mention. On measurement that is what I get. I can convince anybody that that is the amount going through. It is not a rush, I can assure you; an absolutely invisible movement of liquid at that rate. As soon as the fluid touches the clinker it disappears. So far from being a rush it is——

5083. It disappears as it comes into the interior?—Matters can be arranged so that you can see some inches below the surface. It disappears, as it were, altogether. Some of the filters I have inspection holes put into the side so that you can look into the filter, and although the sewage is passing through at this rate—from 1,000 gallons and upwards on the square yard—you do not see any running liquid at all.

5084. (*Professor Ramsay.*) Or dripping—do you see any dripping?—Or dripping. Unless there happens to be an exceptional point of clinker, now and again you may get a drip. As a rule there is nothing visible within that clinker filter all the time.

5085. (*Colonel Harding.*) Surely 1,300 gallons per yard must drop very rapidly?—It drops very rapidly. From the points of the distributor it runs in a little stream.

5086. It runs equally through the whole?—It does not drop.

5087. It runs then?—It has a tremendous distance to come—at least, I imagine so.

5088. This is the effluent from the filter at Horfield?—The first on that table.

5089. What solids in suspension?—I have not got the solids in suspension.

5090. About?—The tank effluent is merely opalescent, that is the way I put it.

5091. About?—I should think five parts.

5092. How many parts are there here?—I do not know. That is entirely different in character from any suspended matter we put on the filter.

5093. You suggested to us that this was really the material of the filter coming out?—Yes.

5094. In this flocculent condition?—Yes, that is.

5095. Is it not possible that matters which were in the tank effluent in solution come out by oxidation into suspension?—You can hardly get a siliceous matter containing particles of carbon from anything but the clinker, and that is what that consists of very largely.

5096. Have you an analysis?—Yes.

5097. What is the analysis of the contents of this little tube?—That is very largely siliceous.

5098. What are the proportions?—I have not got the proportions.

5099. How much organic matter?—I have not got any analysis of these elements. Of course it is quite easy to make, but it collects in quantity, and it is

entirely different from anything that could be produced in sewage at all.

5100. Do you suggest that the effluent of your filter is largely affected by the material of which it is composed?—As I was saying just now, I attribute it to the fact that in house refuse there is a large quantity of vegetable matter burned up with the rest, and I fancy that these kinds of sludge are produced in the combustion and that this does affect the action of the water. For this reason I am trying harder clinker, gas works clinker, and, in fact, I am looking round for harder materials, but the actual loss of substance is so small that although this filter at Horfield has been at work continuously since six months, there has been no destruction of the surface; it has maintained its level.

5101. You do not think any important part of this deposit coming out of your filter is matter which has come through, either in suspension or in solution, and which is irreducible by bacterial action or other forms of reduction?—I think not.

5102. (*Sir Michael Foster.*) Although you have not made an exact analysis of it, you say it is material of the filter?—It is material which could not be produced from sewage.

5103. (*Professor Ramsay.*) They are not in the effluent?—They are not in the tank effluent. The precipitation effluent produced at Horfield is a very good one. We have a very careful man in charge of the works, and there is practically nothing which will settle out in a short time, in a few minutes from the tank effluent at all, it is so finely divided matter that it simply remains opalescent. That settles out, you see, pretty quickly, and is entirely different in character; there is practically no mineral matter in the suspended matter in the tank effluent at Horfield, it is entirely organic.

5104. (*Colonel Harding.*) Were you not surprised to find all this solid matter coming out in your effluent?—I was surprised and annoyed, because we should much prefer it should not come out, but beyond the injury to the appearance of the effluent there is really nothing to complain of.

5105. It is not putrescible?—It is not putrescible as far as my experience goes, and I think can be avoided altogether by the use of a harder clinker. No doubt I shall be able to prove that in the course of a little time. The selection of sufficiently cheap materials to be had in large quantities in most localities is, of course, rather a difficult matter.

5106. It may interest you to know that with Mr. Whittaker's filters at Accrington, he also found a large quantity of solids coming out, but in his case he attributes the solids not to the material of the filter, but the matter in the sewage which is in an irreducible form?—Well, sir, all I can say on that is that I think such matters should not come forward on the filter at all. The bulk of them, at any rate, is retained or should be retained in the tanks.

5107. (*Sir Michael Foster.*) Have you made no bacterial examination of that effluent?—Of this effluent? Well, sir, only on one or two occasions, and these outside examinations involve so much time that I am scarcely able to cope with them, but, rather, to my surprise, there has on each occasion been a considerable reduction in the colonies developed on a gelatine plate. I do not know why there should be. I did not anticipate that, because I encourage bacterial growth as much as I can in the filter. As a matter of fact, 25 per cent. on each occasion on the number of colonies developable in the usual time.

5108. Reduction in the tank effluent?—In the tank effluent.

5109. (*Mr. Power.*) Bacteria of all sorts without distinction of kind?—Of all sorts, yes.

5110. (*Colonel Harding.*) One more question: have you worked your filter at a much reduced rate; have you tried it say at 200 gallons per square yard?—That particular effluent was produced at a particularly low rate of 250 gallons per square yard.

5111. I thought this was the result of 1,300 gallons per square yard?—No; it is Horfield effluent.

5112. At Horfield they work at a greatly lowered rate?—The normal quantity for that strength of tank effluent is 500 gallons per square yard, because that tank effluent is of at least double strength. May I repeat that to make it quite clear? A tank effluent giving about ·5 per 100,000 albuminoid ammonia is taken as a standard. Of that tank effluent the filter will satisfactorily treat 1,000 gallons per square yard. This tank effluent contains, or, rather, gave, 1·1 of albuminoid ammonia per 100,000. It is, therefore, at least double the stock strength, and the flow accordingly has to be reduced to half the quantity. That particular sample was produced as I explained just now, by reducing the quantity to one-fourth, because I wanted to point out to the Commission that this filter is really an instrument of precision: given the depth of the filter, the strength of your tank effluent, you could say how much of that tank effluent you could bring to a required standard, and that is brought inside any standard which could be insisted upon, and the flow is stated on the label of the bottle at 10½ gallons per hour, that is, 252 in the twenty-four hours; but, then, the nitric nitrogen there is 8 parts per 100,000, and is very largely in excess of what is necessary to produce a stable effluent.

5113. Could you not now settle that matter, whether these particles coming out in the filtrate are washed away from the material or not. You could very easily try an experiment of your filters over a six-foot area; you might try an experiment of a square yard area with a material which would not be likely to break down, as, for instance, carefully washed broken bricks or something of that kind, and settle that matter once for all, because it is rather a vital point, is it not, in connection with your work to know whether in the course of filtration there are certain matters which are not reducible, and which must either come out or choke the filter?—Oh, yes, I quite appreciate that.

5114. It would be useful to you and others to investigate that point?—I am obliged to you for the suggestion. That is precisely what I am doing at the present moment.

(*Professor Ramsay.*) I am just reminded Horfield is a barracks, and they get very much the same sort of sewage as they do at Aldershot, exceedingly concentrated at certain hours of the day.

(*Colonel Harding.*) It is domestic sewage.

5115. (*Professor Ramsay.*) There is no manufacturers' refuse in it?—There is no manufacturing refuse in it.

5116. (*Major-General Carey.*) In designing a filter to be worked by your process do you provide a filter area at the rate of 1,300 gallons per square yard, and reduce it, if necessary, afterwards, if the sewage is too strong?—I should endeavour to ascertain the character of the sewage at a given place before I put up the filter. I should take the strongest sewage and measure the quantity; if the strongest sewage represented my stock quality I should then put up the filter at the rate of 1,000 gallons per square yard. If the strongest sewage was stronger than that I should give an additional area in proportion; if it was weaker I would take a smaller area.

5117. (*Mr. Power.*) Do you take the average strength of the sewage or its maximum strength?—I think the proper course is to take the maximum strength and reduce. I know it will take an increased quantity of weaker sewage per week in solution, but the difficulty to meet is to purify the maximum quantity of strongest sewage in any place. I have a sketch of the way in which I should propose to put up a tank and filter, calculated at one million gallons per day, three-fourths of an acre, and the filter could be arranged round the tank.

(*Chairman.*) Then I do not think we need keep you any longer.

5118. (*Dr. Russell.*) How do you clean your gutters?—We have a special brush made which takes the whole of our plate. That is only a few seconds. The sewage is turned off and the brush passed all along the whole plate, including eleven of these gutters. What deposit there is swept off in the sump and it is taken away. There is also a certain amount of solid matter which will have to be dealt with from the tank, and this would go with it.

Mr. William Brown, called in; and Examined.

The Reeves System of Sewage Disposal.

Introductory.

Mr. W. Brown. 20 June 1900.

The Reeves methods of sewage disposal have been applied to out-fall treatment alone, and also to the treatment of sewage in transit alone, and the particulars of these applications about to be submitted will demonstrate the practical advantages of these methods when so applied, but the fundamental principle underlying the Reeves system of sewage disposal in its complete application, is that sewage should travel to the out-fall under such conditions that the air in the sewers will be prevented from becoming impure, not only under those atmospheric influences when natural ventilation may be sufficient to permit of this, but also under those atmospheric changes when natural ventilation becomes impossible.

By the operation of this principle it is obvious that the complete protection of the public health is secured, so far as it at present suffers from the transit of sewage; that all nuisance in connection with the transit of the latter is prevented; and that it arrives at the out-fall in a condition which makes its treatment and disposal there uniformly and comparatively easy.

The Invention.

When the Reeves system is applied in its complete form, the sewage in transit is first dealt with, and by means of an apparatus fixed in selected manholes throughout the sewerage system. From two to four sets of this apparatus are required for every thousand of the population, the number varying with the character of the sewage and the gaseous impurity to be dealt with.

This apparatus consists of two receiving vessels; one to contain a special preparation of soda manganate, which we call Reevozone, and the other sulphuric acid; a drip mixing tray where the manganic liquid and the acid meet, giving off, chiefly, oxygen gas, the liquid at the same time becoming a permanganic liquid; cooling cylinders placed below the drip mixing tray, which receive and cool the permanganic fluid trickling from the latter; a special arrangement of pipes and delivery nozzles carrying the necessary water supply, which liquifies the chemicals and gives the apparatus its automatic action. The water coming in at a pressure is delivered by two nozzles, the first, or higher nozzle, being placed directly over the manganate in the receiver, and the second, or lower nozzle, being almost directly over the cooling cylinders. The lower nozzle produces a very fine spray, which plays upon the cooling cylinder, picking up the permanganic liquid as it trickles on to and down the sides of the cooling cylinders, and beating it up into a fine mist.

The manhole shaft is thus completely filled at all times with strongly oxidising gases and mist. The result is that when the air currents are naturally inwards, the air from the outside passes with these gases and mist down into the sewer, and the combination oxidises and purifies the sewer-air. When the currents are outwards, on the other hand, any gases of putrefaction with which the sewer air may be charged are completely oxidised and purified by contact with the same gases and mist before escaping from the grating.

The water supply pipe is fitted with a double locking water-seal to protect the water-main from any possibility of sewer-gas contamination by back pressure. The whole arrangement is under complete control, and is put in motion, or stopped, by turning the water supply tap, by which also the chemical power may be regulated to any required degree of strength.

The action of the apparatus being independent of atmospheric conditions (although the fullest use is made of such as are favourable to natural ventilation) is available even under those atmospheric conditions, when natural ventilation must come to a standstill altogether.

The purification of the sewer-air is thus insured by the treatment of sewage in transit, as described; but the sewage itself is also affected in two ways, as follows: First so far as the permanganic mist is not spent in purifying the gases it mixes with the sewage and with anti-septic results; second, as the sewage travels through sewers where the air is pure, putrefaction proceeds less rapidly than it would do where the air has become polluted.

When the sewage arrives at the out-fall, should any further deodorisation be required, this is effected by the use of proto-sulphate of iron, applied by means of a special liquefying apparatus. This apparatus consists of a receiver fitted with a water supply, the action of which is similar to that of the Reevozone liquefier. The sewage then flows into a precipitating tank, sometimes the precipitants are added to the sewage as the latter flows to the tank, but we find it sometimes advantageous to add the precipitants after the tank has filled.

We find it is necessary to vary the precipitating treatment just as we find it necessary to vary the deodorising treatment.

Generally we use a preparation which is both a precipitant and a deodorant, and which we have named "thamisin." This, in the form of a thickish cream, is put into a closed vessel. Pressure is brought to bear upon the surface of the "thamisin," which is ejected with force from a nozzle, and played upon the surface of the sewage in the tank. Precipitation takes place immediately. "Thamisin" is a preparation of tar and lime made by special apparatus, and is sometimes made and used in the form of a thick cream as mentioned above, but it is also sometimes first made into blocks and afterwards liquified automatically, and used in the same way as the proto-sulphate of iron. During night operations especially we find an advantage in this latter method of use.

If suitable land be available the effluent is run over its surface for final purification, the chemical treatment increasing the purifying power of the land. The sludge, which is without offensive odour, is removed in waggons and discharged into ploughed trenches and left to solidify. After a few hours, owing to the thamisin treatment, it is ready to be ploughed into the land as a fertiliser.

Where no land is available for filtration, or where it is restricted, we use a special method for producing final purification. The effluent is ejected in the form of a fine mist on to an artificial filter-bed composed of sand or any suitable filtering material. By this means it is brought into contact with the oxygen of the air in a very finely divided condition, and oxidation takes place with great rapidity.

As our filters may be but from three to twelve inches deep we can place one above another, and so effect a large amount of filtration upon a comparatively small area of ground space.

We find that the oxidation of the effluent is facilitated if it is chemically treated before being sprayed on to the filter, but such questions as to whether chemicals should be used or not, or in what proportions, or whether the filters should be superposed, and what number of tiers should be in one stack, can only be answered in connection with the local advantages or absence of them in any particular case.

The efficient and economical oxidation of the sewage matter is the chief object aimed at throughout the Reeves system, but a subsidiary object of some importance may be pointed out, namely, the return of the sewage to the soil, the possibility of this being done to advantage being greatly increased in the practical application of the system, and the scientific reason for which, being apparently furnished by the results of recent bacteriological investigation.

The Advantages Claimed for the Reeves System.

First:—As it begins by preventing the formation of sewer-gas, it secures the safety of the public health up to such extent as it at present suffers on account of air pollution by sewer-gas.

Second:—Its adoption will minimise the public burden in respect of the sewage disposal question.

Third:—It allows of the fullest advantage to be taken of all local and natural advantages in any particular case.

Fourth:—It provides efficient substitutes where local advantages are few, or even absent.

Fifth:—It, to a considerable extent, prevents the sewage difficulty by rendering it easier to deal with all nuisance from sewage on its way to, and at, the out-fall.

The Grounds on which the Advantages Claimed for the Reeves System are Based.

The Prevention of Sewer-gas.

This claim rests upon the results of actual practice. Amongst the installations for this purpose that may be mentioned are those at Epsom, Fulham, and Edinburgh. At Edinburgh the installation now consists of fifty-three

apparatuses, forty-four of which are working in connection with a main intercepting sewer 9 feet 3 inches by 7 feet 2 inches, which drains a large district of Edinburgh, as also certain villages for several miles above Edinburgh. The ventilating gratings in these sewers had all to be closed owing to the nuisance to which they gave rise, but since the application of the Reeves system the gratings have been re-opened, and no nuisance has been experienced. In every case where the system has been applied the same result has followed.

Improvement of the Public Health.

While the prevention of sewer-gas implies an improvement in the public health, it may be noted that this is an effect which is found actually to accompany the application of the Reeves system. In this connection I may be permitted to point out that the conditions which we know to be favourable to the production of sewer-gas are always concurrent with increased mortality and sickness returns. From experiments we have found that gases from the top of a high ventilating shaft on a main sewer of the London County Council are sometimes of a highly dangerous nature and are not rendered innocuous on coming into the air, but will enter rooms on the ground floor of houses 86 feet away in a highly dangerous condition. In January last we found these gases to be in a specially dangerous condition, and concurrently the vital statistics for London showed the diseases of the respiratory organs for the week to be 558 above the corrected average.

I may also be permitted to point out how the health of members attending the Houses of Parliament is sometimes seriously endangered from sewer-gas. Under present practice sewer-gases of a dangerous character are liable to be expelled from the Metropolitan sewers in the vicinity of the Houses, and if the weather at the time is close and muggy, and the wind in any direction from N.W. to S.W., air vitiated by these gases will be wafted into the Houses by the corridors.

Minimises the Public Burden.

The results at Henley and Staines out-falls bear out this. Previous to the Reeves system being applied at Henley the weekly cost of treating the sewage was about £16 per week. The cost per week under the Reeves system is only £9 10s. per week, and with regard to Staines the local authorities were in a difficulty, a perpetual injunction having been obtained against them, and were contemplating an expenditure of £7,000. Which expenditure was rendered unnecessary by the introduction of the Reeves system. This point may be illustrated by the following reference to the case of London. Taking the population at 5,000,000, I estimate that the annual cost for keeping the air in the sewers pure continuously would be about £30,000, including repayment of capital expenditure. Now, the annual expenditure in connection with preventible diseases in London is at least £500,000. If, therefore, a reduction of only 10 per cent. of this expenditure be estimated as the result of the continuous purification of the sewer-air, we have a saving of £20,000 per annum in cash alone.

Again, looking at the case of London from another point of view, the engineering difficulties arise as follows:—If large sewers are provided, with a view of preventing the recurring flooding evils owing to heavy rains, we then have during dry weather large, and comparatively empty, underground chambers in which bad gases are formed and stored in highly dangerous quantities, but with the Reeves system the flooding evils can be avoided without the formation of the dangerous gases, and without the necessity of increasing the present main drainage system.

Allows the Fullest Advantage to be taken of Local Circumstances.

At Henley, the land naturally so suitable for sewage disposal was, and is, by itself quite unequal to deal with the bad sewage there; but since the application of the Reeves System the effluent has been sent straight from the precipitating tank on to the land without nuisance.

Provides Efficient Substitutes where Local Advantages are Few or Absent.

At Staines, again, the land was not naturally suitable for sewage disposal, the top soil being four parts clay and one part sand to a depth of three feet, yet, by the use of the Reeves chemicals and appliances, the land there was enabled to take all the sewage for two-and-a-half years without difficulty or nuisance, and this notwithstanding that a perpetual injunction had been obtained against the Staines Council in respect of nuisance from their works previous to the introduction of the Reeves System. Effluents drawn from the subsoil by tube-wells gave the following analyses:—

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Sample of Effluent from Tube-well 19 feet down in centre of Works—

	Grains per Gallon.
Ammonia albuminoid	·0540
Chlorine	16·800
Nitrogen as nitrates	·0490

Sample of Effluent from Tube-well 15 feet deep towards the Eastern boundary of Works—

Ammonia albuminoid	·0770
Chlorine	14·000
Nitrogen as nitrates	·0320

Since these analyses were obtained excavations have been made right through the land to a depth of 20 feet, and no trace of sewage matter has been noticeable either on the surface of the land, the faces of the excavations, or the water in the bottom of the cutting.

Prevents Nuisance in the Streets and at the Out-fall under all Conditions, and so makes the Sewage Difficulty Easier of Solution.

The proof of the first part of this claim is evident from the experiences already quoted, and the conclusion in the second part follows from the first, for it is the necessity to avoid nuisance which increases the engineering difficulties of transit and limits the choice of out-fall sites.

There is no place where the Reeves System can be inspected in its complete form; but an inspection of the installations at Epsom, Fulham, or Edinburgh, for its practical working in the sewers, and that at Henley-on-Thames, for its working at the out-fall, will give a good idea of its working in its complete application.

At Henley-on-Thames, as the land does the final purification, we use the special filtering arrangement to give a supply of pure effluent sufficient for the purposes of our operations only, namely, the water supply for liquefying our chemicals and what is required for our steam boilers—about 10,000 gallons daily; but at a few days' notice we could arrange so that the special filter could take the whole of the daily flow, of about 100,000 gallons.

The Cost of the Reeves Process.

The cost of the Reeves system varies with the conditions. At Edinburgh some of the apparatuses cost annually £2 each for chemicals, and others £3; the water costs about £3, and the labour attending to them about £3. But the work each apparatus has to do there is exceptional, some of the apparatuses doing effective ventilation equivalent to twelve miles of a 12-inch pipe sewer, running quarter full, to each apparatus.

Again, at such places as Epsom the annual cost has been small, because it has not been the practice to keep the apparatus continuously in use there throughout each year.

So far as can be at present estimated the annual cost of maintaining the system throughout the whole of the sewerage of a town or large district would be under £2 per apparatus, but there would be a saving in actual cash value that would fall to be set off against this as has been indicated in the paragraph referring to the minimising of the public burdens on page 23.

As to the cost of out-fall treatment, I cannot point to any case laid down on the Reeves method from the first, but a comparison of the cost of the Reeves process with the cost of the systems in use previously where it has been applied gives a great advantage to the Reeves system.

It may be noted that, so far, the Reeves system has only been applied in cases where difficulty with existing methods had caused the local authorities grave concern.

5119. (*Chairman*). You are Mr. Brown?—Yes, my Lord.

5120. And you come before us representing the Reeves Chemical Sanitation Company's process?—Yes.

5121. The Commission are very much obliged to you for your statement, which we have all read with interest, and which will be placed upon our minutes. We do not propose to ask you much now, because we understand that you invite us to examine for ourselves the results of your system. Well, we shall be very happy to do that, and will you tell us where you would like us to

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examine it?—With regard to the first part of the treatment we have a very good installation at Edinburgh, a large installation, and another at Epsom, and a smaller one at Fulham. Fulham, of course, is the nearest place, and as one of the apparatus is placed just at the discharge from Kops' Brewery, where it is a very severe test, it illustrates the power of the apparatus sufficiently. But at Edinburgh you would see the system, as such, applied on a large scale with fifty-three apparatus running for the most part in series. Then with regard to the outfall treatment, we could show that in its entirety at Henley.

5122 (*Colonel Harding*). Your system is largely a system of treating sewage in transit so as to prevent objectionable smells by decomposition arising sooner than the arrival at the sewage works?—Yes, that is a very important part of the system.

5123. In the main the system at the sewage works consists of precipitation, the precipitant being a special one of your own, consisting of tar and lime, and the precipitation is followed by passing the effluent on to the land?—Yes.

5124. But you suggest an intermediate method which you do not fully explain, of producing what you call a fine mist of sewage which is to pass over three inches of sand?—Yes; we can show that at Henley.

5125. But how do you produce this fine mist?—By pressure through a nozzle, a specially shaped nozzle.

5126. How do you produce the pressure?—At Henley we are doing it by steam power.

5127. What pressure?—Well, about equal to a column of water about 50 feet high.

5128. Do you suggest that that is a practical way of dealing with sewage on a large scale?—Yes; under certain circumstances where there are difficulties in respect of ground space and other difficulties of that kind. At Henley we do not use that in our practical dealing with the sewage, of course.

5129. This fine spray is produced by passing through holes?—Through one hole, one hole on each nozzle, the liquid striking on a plate, and spreading out into a fine mist which is effectively oxidised by intimate atmospheric contact.

5130. You have done that within practical limits of cost?—Yes, we are using the water by the process for our own purposes.

5131. And the treatment of sewage in that way is practical?—Yes, the filtration is chiefly to take away any rough things that may be in the effluent—grit or anything of that kind.

5132. Thank you very much, Mr. Brown. I do not want to detain you?—That is a sample of the effluent by this mist process, and entirely without having touched land, or having been filtered in the usual sense (*producing sample*), and is similar to one on which Professor Wanklyn reported, as follows:—

—	Grs. per Gallon.		Parts per Million.		Opinion.
	Chloride.	Nitrates.	Free ammonia.	Albuminoid ammonia.	
Raw sewage -	—	—	140·00	5·50	Strong sewage.
Tank effluent -	—	—	15·00	2.00	A moderately good effluent.
Final effluent -	6·5	9·3	0·00	0.50	An excellent effluent.

5133 (*Chairman*). We shall take our samples, of course?—Yes.

Mr. William Cameron Sillar; called in, and Examined.

Mr. W. C. Sillar.

Particulars of Evidence with reference to the "A.B.C. Sewage Process," offered by the Native Guano Company, Limited, to be given by their representatives, Mr. William Cameron Sillar (a Director of the Company and one of the original patentees) and Mr. Douglas Archibald.

Comprising a description of:

(1) The invention.

(2) The advantages claimed it.

(3) The grounds on which the claims are supported.

(4) The cost of the process, and a statement giving the name of the place where the process is at present in operation, and showing on what scale and during what period it has been in use.

(1) The Invention.—The invention is the combination of certain natural substances which when added to town sewage deodorise and purify it, precipitating its impurities so as to leave the effluent water in a fit condition to flow into ordinary rivers and the precipitated deposit a valuable manure.

These substances are principally
Clay,
Carbon,
Blood, and
Salts of Alumina.

Should the sewage be too acid, some alkali would be used to neutralise it. Should it be too alkaline, a little acid is added. These substances are used in the following manner: First, the sewage is treated with a triturated mixture of clay, carbon, and blood, which at Kingston is added to it in the pumpwell before it is raised to the tank level. It is considered preferable to add this mixture to the sewage at the earliest possible stage after it reaches the works. These substances together act as deodorants and purifiers. Subsequently a solution of alumina is added in the channel leading from the pump delivery to the tanks. The exact proportions in which these substances are mixed and added to the sewage vary with the strength of the latter, but the average proportions may be inferred from the following figures for the materials used at Kingston:—

Clay, Carbon, Blood, and Salts of Alumina - - - - Grains per Gallon. 50

When the sewage thus treated passes into the settling tanks precipitation occurs, which not merely deposits the grosser suspended matters, but a large proportion of the dissolved impurities which have attached themselves, both chemically and mechanically, to the clay, carbon, and blood. The resulting effluent water is rendered fit to be discharged into ordinary watercourses, and the tank precipitate is in a condition for removal and conversion into a portable manure, which is effected in the following manner:—

The precipitate in the condition of sludge containing about 90 per cent. of water is removed from the tanks into filter presses, which reduce it to a cake containing about 50 per cent. This cake is further dried by artificial heat or otherwise until it contains about 20 per cent. of moisture, after which it is bagged ready for use.

(2) The advantages claimed for it.—It is claimed for it:

A. That by means of the clay, carbon, etc., used in combination in the precipitating tanks the offensive odour is at once removed from the sewage, and this inoffensiveness continues to the end of the process.

B. The resulting tank effluent is alone of sufficient purity to be discharged into any ordinary river, as may be judged of from analyses of albuminoid ammonia in samples taken by the Medical Officer of Health at Kingston and the Company's Chemist and Works' Manager at Kingston during the past two years, the monthly averages of which appear in the adjoining tables (pages 1 and 2), the yearly averages being as follows:—

—	Albuminoid Ammonia. Parts per Million.	
	1898.	1899.
Medical Officer of Health.	52 Samples, 2·04	47 Samples, 2·24
Company's Chemist	57 Samples, 1·96	36 Samples, 2·08
Average of the Two - - -	2·00	2·16

The average proportion of albuminoid ammonia in the crude sewage at Kingston may be inferred from the following results of analyses made at Kingston under the superintendence of the company's chemist.

December 11th to December 29th 1899.	Albuminoid Ammonia. Parts per Million.
Average of Daily Samples of Sewage taken every Fifteen Minutes	12·6

C. Where a higher standard of purification is required this can be effected by a single filtration of the tank effluent through a coke or ash filter at the rate of about 310 gallons per square yard per 24 hours. The two filters at Kingston are about 1-200th of an acre each in area, and have been worked regularly since May, 1898, on the intermittent principle, viz.:—

20 minutes filling.
2 hours 25 minutes standing.
45 minutes emptying.
30 minutes standing empty.

4 hours.

i.e., a total of 4 hours or three fillings in 12 hours. They have hitherto been worked only in the day hours. So far as can be ascertained by actual measurements there is no sensible loss of capacity.

D. Fish are in no way injured by the effluent.

E. The absence of evil odour enables the works to be set up in close proximity to dwellings or towns, thus dispensing with the necessity of lengthened sewerage.

F. The salts of alumina precipitate without injuring the manurial value of the deposit, and in this respect the process differs essentially from the lime treatment and many others. The manurial value of the deposit which is derived solely from the action in the tanks upon the sewage may be inferred from the fact that it has a ready sale at £3 10s. per ton.

G. The finished manure being in a portable and inoffensive condition can be conveniently sent to any part of the country, and this of itself affords a guarantee against the offence arising from accumulations of unsaleable sludge in situ.

H. The cost of the process is no greater, if indeed not actually less, than that incurred in the various alternatives in use or proposed, and with this additional advantage that it supplies a home product for the benefit of national agriculture in place of the wanton destruction involved in so many other systems, and the consequent necessity of importing fertilisers from abroad.

I. The capital cost of works suitable for the entire process is under the low figure of 10s. per head of the population.

(3.) The grounds on which the claims are supported.—In regard to the specific claims above made the grounds on which they are supported are—

A. The works themselves at Kingston, where the process has been in continuous operation for nearly 12 years. The evidence given by Sir William Crookes, F.R.S., etc., the late Dr. Tidy, M.B., M.R.C.S., etc., the late Professor Wallace, the late Professor Way, F.I.C., F.C.S., etc., the late Mr. T. W. Keates, F.I.C., etc., the late Dr. Angus Smith, F.R.S., etc., Dr. Collingridge, M.B., M.R.C.S., etc., Mr C. Hawksley, C.E., etc., Mr. Baldwin Latham, M.I.C.E., etc., before the Privy Council, 1882. The report of Professor Dewar, F.R.S., and the late Dr. Tidy, on a three months' examination of the working of the process at Aylesbury. The annual certificates of the Aylesbury Local Board. Evidence given by the late Dr. Frankland, F.R.S., etc., on the results of the working at Kingston. More recently Colonel Hasted, R.E., Deputy Chief Engineering Inspector of the Local Government Board, visited the works at Kingston-on-Thames, on the 10th February, 1900, and made the following remarks in the visitors' book:— *Mr. W. C. Sillar.* 20 June 1900.

> "I went all over the works, and I found them remarkably free from smell. I examined samples of the effluent—that from the tanks was fairly clear without noticeable smell of sewage, that from the filters was perfectly clear, and without smell."

The fact that the Kingston Corporation, after two years' experience of the works, converted the land adjoining into a pleasure park, and constructed the band stand within 25 yards of the precipitating tanks.

B. The reports and evidence of the above mentioned chemists and engineers and others.

The tank effluent at Kingston until the recent rise in the requirements of the Thames Conservancy has, since the year 1888, been allowed to pass into the Thames without objection.

C. The sewage of Kingston, Surbiton, and Hampton Wick, with a population at present over 50,000, has hitherto been treated upon an area of not more than three acres. When the standard requires the tank effluent to undergo further purification the results from two years with experimental coke filters at Kingston have shown that it can be purified to the requisite standard in the proportion of 1½ million gallons to the acre. Thus only 1¼ acres more will be requisite.

The results of analyses of samples of the filtrate from the above-mentioned filters from August, 1899, to February, 1900, are given in a table annexed, the averages being as follows:—

	Albuminoid Ammonia, Parts per Million.
Coke Filter, 11 Samples	·77
Ash Filter, 12 Samples	·69

D. As evidence that the effluent is innocuous to fish life, medals were received from every fisheries exhibition for fish living in tank effluent.

E. The case of Kingston.

F. and G. The fact that for the last thirty years all the manure has been sold at an average price of 70s. per ton. The twenty-three annual collections of reports received from farmers, gardeners, and others who have used the manure.

H. This can be shown from the fact that Mr. T. Hawksley, C.E., at the inauguration of the completed Kingston Works on 29th June, 1869, stated that:

> "He was told that this Company undertook to purify the sewage as they had seen it done that day for a compensation amounting to only threepence in the pound. He had had large experience in this subject as an engineer, and financially he could tell the town of Kingston that it was only paying one-third and in many cases one-fourth of what other towns had to pay."

The fact that Kingston is only paying about £4,000 per annum for about 52,000 persons.

I. The fact, and a comparison of the cost of the works at Kingston with the cost of works at other places.

(4) The cost of the process.—The cost of the process is as before stated under 10s. per head of the population for first construction; and for daily working the Kingston Corporation, as above mentioned, pay a subsidy of £4,000 per annum for 52,000 persons. The Native Guano Co. make a profit by the subsidy paid by the town together with the proceeds of the native guano sold.

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The cost to the town is limited to the subsidy they agree to pay to the Company for carrying on the work, and the Company guarantee the results.

Where in operation. On what scale and during what period it has been in use.—The process is at present in operation at Kingston-on-Thames, dealing with the sewage of that borough and of the districts of Surbiton and Hampton Wick with an aggregate population of 51,524. The quantity of sewage dealt with amounts at present to about 700 million gallons a year. The works have been in continuous operation from the 4th December, 1888.

The directors of the company would desire to repeat their former invitation to the members of the Royal Commission to visit their works at Kingston, and would be pleased to place every facility at their disposal for making complete examinations and analyses of the system which is there in operation.

The Royal Commission would thus be enabled to judge for themselves of the efficacy of the system, as it is now carried out with all the improvements gained by thirty years' experience and eleven years' continuous working at Kingston.

The fact that the process has been in existence for so many years, and has worked successfully, as the foregoing evidence shows, justifies the directors in asking the Royal Commission to examine it, and judge of its merits by what it is doing to-day rather than by conclusions arrived at 30 years ago, based on a few hours' examination of the working under abnormal conditions when the process was in its first or experimental stage.

It is deemed advisable to refer to this, as doubtless the attention of the Royal Commission will be called to the report upon the process by the Royal Rivers Pollution Commission of 1868.

The conclusions arrived at by that Commission have always been contested by the Company. They were based on (1) a small experiment made at Leicester, where an examination was made immediately after the process was started, and before even the original patent had been completed, and (2) upon experimental working at Leamington, where the process had only been in operation a few months, at works of which the company had only temporary possession.

To judge any process at such an early stage in its history, and to arrive at such conclusions after only a few hours' examination, was manifestly premature, and it is submitted that apart from the question of the experiments, as then conducted affording any partial grounds for such conclusions, these in no way apply to the process, as it is now worked at Kingston, while they have been completely refuted, and reversed by the investigations (1) of Sir William Crookes, F.R.S., who personally supervised the working for 12 months, and (2) of Professor Dewar, F.R.S., and the late Dr. Tidy, who personally examined the working at Aylesbury, and appointed a resident chemist of their own to supervise the works for three months.

These gentlemen came to the same conclusions as Sir William Crookes, and they are summarised as follows:—

(1.) That the A B C process produces a clear effluent free from suspended matter, and devoid of smell.

(2.) That the effluent is uniform, notwithstanding the very varied nature and concentration of the sewage.

(3.) That as the strength of the sewage increases, the precipitation is more complete.

(4.) That the process removes over 80 per cent. of the total oxidizable organic matter.

(5.) That it precipitates 60 per cent. of the organic matter in solution, and of the residue left in the effluent at least two-thirds are non-albuminous, and, therefore, of a nature less liable to putrefactive and other changes.

(6.) That the process is carried on without nuisance, the sewage being immediately and completely deodorized, and the entire works free from any objectionable smell.

(7.) That it produces a manure containing an average of 3·8 per cent. of ammonia, calculated on the perfectly dry manure, or if with 20 per cent. of water, 3 per cent. of available ammonia, and also 5 per cent. of phosphates, reckoned as tricalcic phosphate of lime.

The evidence of other scientists already referred to corroborates these results, while the practical working, both at Kingston and Aylesbury, between them cover a period of 24 years.

It may also be noted that Dr. Frankland, himself a member of the 1868 Commission, modified his opinion of the process upon a later examination of it as working at Kingston, and he stated in evidence that the effluent as examined by him was of sufficient purity to be admissible into the Thames below the intakes of the water companies.

ANALYSES OF EFFLUENTS FROM KINGSTON SEWAGE WORKS.

MONTHLY AVERAGES of results reported by the Medical Officer of Health, from figures supplied by Town Clerk.

ALBUMINOID AMMONIA—PARTS PER MILLION.

Month.	1898. 52 Samples.	1899. 47 Samples.
January	1·40	2·47
February	1·52	—
March	2·24	2·55
April	1·96	2·28
May	2·07	1·90
June	1·70	1·89
July	2·23	2·47
August	2·93	—
September	2·23	2·14
October	2·21	2·22
November	1·86	—
December	2·10	—
Averages	2·04	2·24

All tank effluents without any filtration.

ANALYSES of EFFLUENTS from KINGSTON SEWAGE WORKS.

Monthly averages of results reported by the Company's Chemist and Works Manager.

ALBUMINOID AMMONIA—PARTS PER MILLION.

Month.	1898. 57 Samples.	1899. 36 Samples.
January	1·88	2·23
February	1·82	—
March	2·05	1·50
April	1·80	2·14
May	2·36	2·55
June	1·98	1·25
July	2·12	2·16
August	2·30	2.45
September	1·80	2·26
October	1·70	2·26
November	1·84	1·96
December	1·90	2·18
Averages	1·96	2·08

All tank effluents without any filtration.

ANALYSES of FILTRATES from Experimental Filters, KINGSTON SEWAGE WORKS.

ALBUMINOID AMMONIA—PARTS PER MILLION.

——	Coke.	Ash.
1899.		
August 8	·12	—
„ 9	—	·87
„ 28	·91	·79
September 26	·84	—
October 25	·68	·64
December 11	·96	·87
„ 15	·85	·82
„ 19	—	·99
„ 20	·81	—
1900.		
January 3	—	·57
„ 9	·60	·52
„ 20	·64	—
„ 29	·64	—
„ 31	·70	·61
February 8	—	·63
„ 12	—	·48
„ 14	—	·42
Averages	·77	·69

Each of the above experimental filters is $\frac{1}{110}$th of an acre and they have been working continuously from May 1898.

6134. (*Chairman.*) You are Mr. Sillar?—(*Mr. Sillar.*) I am Mr. Sillar. I have taken the liberty to bring my secretary in case questions are asked which he may be able to answer better than we are ourselves.

6135. And you are Mr. Archibald?—(*Mr. Archibald.*) Yes.

6136. You come as representing the A.B.C. Sewage Process?—(*Mr. Sillar.*) I am a director, and Mr. Archibald is our representative.

6137. The Commission are much obliged for the statement you have given us, which I believe all of us read with interest, and which will be placed upon our minutes. I do not think that now we propose to ask you very much because we understand that you invite us to make examinations for ourselves?—Certainly.

6138. And that we shall be happy to do. You will perhaps let me know where you would wish our examinations to take place?—(*Mr. Archibald.*) Do you mean the examinations of the works at Kingston?

6139. At Kingston?—Well, it is the only place at which the company is at present carrying on operations, and I should imagine that would be the only place where you could examine the system.

6140. (*Colonel Harding.*) May I ask Mr. Archibald how old this system is; how long it has been before the public?—I think the system began in 1869.

6141. And did I understand you to say just now that the only place in which it was in operation was at Kingston?—At Kingston, yes.

6142. Can you give us some explanation of how that is?—Yes, of course, that is rather a lengthy process because it would mean stating the reasons why the company was not at certain places where they began to be, but if you will allow me I will put before you—I think I have the evidence here.

6143. Would you say it has been tried at many places, has it not?—When it was originally started it was supposed that the process would yield such a profitable sludge manure that the process would be able to be carried on without any payment on the part of the town. The consequence was that arrangements were made with several towns to start with upon rather too optimistic a basis. Those arrangements were begun and carried on to some extent at some of the places, and then it was found that it was impossible to go on with the contract as originally made, and the company had to retire from some of these places and begin afresh on a different financial basis. That was the reason that operated in the initial stages, and I think that, to a certain extent, the results have rather operated against the interests of the company all through. Having begun like that, it was natural that everybody referred back to the past and said, "If you did not succeed there, why should you succeed here?" But I could give you very good reasons why in individual cases the company is not carrying on operations. I could give you the specific reasons.

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6144. You now find that the sludge produced by your system has not the manurial value? That it was originally supposed to have?

6145. But you still suggest that it has a manurial value?—We claim that it has a manurial value to the farmer equal to what he pays, viz., the £3 10s. per ton.

6146. At Kingston does the farmer pay £3 10s. per ton?—The farmer to whom the manure is sent pays £3 10s. per ton all over the Kingdom.

6147. (*Professor Ramsey.*) The manure that is sent out is not merely the sludge, but it is the sludge plus a number of other ingredients, is it not?—It is not plus any ingredients that are not used in the treatment. It is simply the substances that are put into the tanks for the treatment that appear in the sludge; just in the same way as lime or any other treatment would appear in the ultimate sludge.

6148. (*Colonel Harding.*) Then the question arises whether the cost incurred in providing these materials does not counterbalance the price that you obtain from the sludge?—I think I can give you very good evidence to show that it does not.

6149. As a fact, your scheme was tried at Leeds thirty years ago?—At Leeds; yes—that is many years ago and it was tried. I might read you if you will allow me a description of why it was at Leeds and the history of it in fact.

6150. Do not give us the history. Could you tell us in a few words why it was abandoned by Leeds?—I cannot tell you without reading the paragraph.

6151. Was it disappointment as to the value of the sludge?—Perhaps if you would allow me, this is rather going back into past history and Mr. Sillar——

6152. I do not want to raise the whole history of the Leeds experiments?—(*Mr. Sillar.*) At Leeds the Corporation made certain scientific experiments as to the value of the manure, and they came to the conclusion that it was of more value agriculturally than stable refuse or any other manure they tried; they were perfectly satisfied with the value of the manure, but they never paid the company any subsidy for treating their sewage, and they got tired after two or three years of doing it for nothing.

6153. And the Leeds Corporation did not find it worth their while to carry it on?—When the official from the Local Government Board visited Leeds he said: "I do not see why these people should be at the expense of putting such clear water into such a filthy stream," and the Leeds Corporation, whenever they are required to purify the water to a certain extent, know now how to do it, but the stream into which the clear water went was a filthy black stream, and that was the reason that the Leeds Corporation——

6154. Without going back, then, into the history of the particular experiment, may I ask you at the present moment what is the position of the system. You suggest it as a system of precipitation, and you do not suggest, do you, that the effluent coming from the tanks ought not to be further treated?—(*Mr. Archibald.*) Most certainly we do not.

6155. You suggest that it does not require further treatment?—No, no; most certainly we do allow that it should be filtered.

6156. Then we are to look upon your system as a system of precipitation?—Of precipitation, yes.

6157. Which is to be followed by some other system of lime treatment or artificial filtration?—No; pardon me, there is no other treatment wanted. Our system is a system of treatment by precipitation plus subsequent filtration over coke.

6158. Yes, but so far as the special features of your system are concerned, they apply to the first stage of the treatment?—So far as the special features, the precipitation refers certainly to the first stage.

6159. Then we are to look upon what you bring before us as one of the forms of precipitation?—As one of the forms of precipitation, yes; well, precipitation with purification of the sewage to a point which we also claim to say is very much higher than any other mode of precipitation in existence.

6160. I see that you suggest in certain cases you can bring by simply your system of precipitation from aver-

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age sewages the albuminoid ammonia down to ·2?—Yes, down to two parts per 1,000,000.

5161. ·2 per 100,000?—Yes, ·2 per 100,000.

5162. From what strength of sewage do you suggest that that might be done, and what would the albuminoid ammonia be in the crude sewage?—The albuminoid ammonia in the crude sewage at Kingston, from which we got those figures from an average of daily samples taken every fifteen minutes between December 11th and 22nd, was 12·46 parts per 1,000,000.

5163. It is not a particularly strong sewage; it is a fair average sewage?—That is a reduction from 12·46 to the average which we get, which is about ·2 parts per million.

5164. But, clearly, even the effluent containing only ·2 per 100,000 albuminoid ammonia would require further treatment by either land filtration or artificial filtration?—In the event of the standard requiring it to be lower than ·2. (*Mr. Sillar.*) Up to this time it has been found sufficient by the Thames Conservators. It has passed their requirements, but we thought it better to supplement it with one filter.

5165. Undoubtedly you would have subsequently decomposition of such an effluent containing that amount of albuminoid ammonia?—(*Mr. Archibald.*) Well, we do not seem to affect——

5166. Have you tried any incubator tests?—We have not tried any incubator tests; but we find that we get such a much better result by filtration over one filter, that we have adopted that as the means by which we can purify up to the required standard.

5167. Then, briefly, what you put before the Commission, is that by your system and precipitation you are giving better results in regard to that first stage than by any other process?—Yes, I think that is one of the main points. And may I mention another point which is an advantage, because, of course, we claim other advantages. One is, that by means of the value of the sludge which is sold as manure at £3 10s. a ton, we are enabled to charge the town a subsidy which, in most cases, is below that of the expense of producing any effluent of a similar character by ordinary precipitation without the production of the saleable manure.

5168. (*Professor Ramsay.*) I do not know if it is a fair question to ask you, is it a secret process in any sense, or is it open, to say what you put into the crude sewage?—No; the patent—it is originally a patent process by which certain substances which are principally these below, are put into the sewage and used as precipitants and absorbents. The only secret at present is that the company, by experience, has found the best proportions in which to use those materials, and, of course, that, to a certain extent, is a trade secret which one does not like to tell everybody, as they might easily use it themselves. I may say that in name of the company——

5169. (*Chairman.*) Of course, this evidence will be published, so do not say anything you do not want to?—No; I was only going to say that the company had no desire to withhold any of these points from the Commission provided it would be not published explicitly in the Report.

5170-1. (*Professor Ramsay*) One other question I should like to ask: In preparing the substances for manure, is it sold as such, or is not there anything else intermixed with it; do you mix nitrate of soda or phosphates, or anything else with it to supply the particular quality to the manure, or do you simply use it as such?—No. The only alteration made in regard to the treatment is, when the sewage varies from acid to alkali, there is a slight alteration in the substances put in, but this has nothing to do with the manure. It is left to the ultimate effect. (*Mr. Sillar.*) As our object was to prove that the resulting manure has agricultural value, we have been very careful, indeed, to add nothing to it to give an artificial value. If we were to put in anything for trade purposes, making specified manures for specified crops, people would say the value was owing to that addition, so, on principle, we have never done it; the manure we sell is solely the purifying elements put in, in addition to what is taken out of the sewage.

5172. One other question I should like to put. You run your effluent into the Thmes, I think?—(*Mr. Archibald.*) Yes.

5173. Has there been any difficulty at all with the Thames Conservancy Board, or with any Authority, as regards the effluent?—No complaint regarding the effluent at Kingston was made by the Thames Conservancy before 1895. The works, I may say, were in operation in December, 1888, so that for seven years there was no complaint made by the Thames Conservancy. (*Mr. Sillar.*) Then they raised their standard. (*Mr. Archibald.*) Their new Act was, of course you know, passed in 1894, and they began to raise their requirements, at all events, if not their standard, and they have complained once or twice since then of the effluent. I may say to you I have got a list of the effluents made by the Thames Conservancy.

5174. (*Colonel Harding.*) We have heard of a standard of the Thames Conservancy; do you know what it is?—I am afraid not; it is one of those unknown quantities which nobody seems to know. We have a sort of idea what it is from what they say in regard to the analyses, and from the remarks they make; but they have different standards for different parts of the river. For below intakes they have one standard, for above intakes another, for below intakes and above locks they have another. The last sample that I have on this list 1898, June 25th, 2 albuminoid ammonia is put down as not a bad effluent; well, that is just about the average that we get. Then, when they get up to 4 occasionally, or 3, or thereabouts, then it becomes unsatisfactory. And then they put 1·1 a fair effluent, so that it is to be inferred that "one" is a fair effluent—and yet in another case, I may say 2 is put down here as a fair effluent.

5175. But you said ·2 was not bad?—Yes, but they put 2 "very unsatisfactory" in another case.

5176. And 1·1 only fair?—Yes. One cannot exactly make out what they mean: "June 1st, 1897, 2 a fair effluent"; then "June 25th, 1900, 2 not a bad effluent."

5177. There has been no filtration in your case?—No; no filtration; those are two from the tanks. Then directly the complaint occurred, the company called the attention of the Kingston authorities to the fact that they should put down a filter, and they have been trying ever since to persuade the Corporation to put down a filter, to filter their effluent, and now I believe the Corporation are proposing to put down a filter forthwith. That is to complete the works, because when the company first started they thought that the tank effluent would be good enough for the requirements, and it was good enough for the requirements as they were; then since the requirements have been raised, the company have naturally called upon the town to put down the additional works necessary to raise the standard of the effluent to the standard required. That was in their original agreement; there was a clause in their agreement with the Corporation, which is rather important, because it shows that the company, when they first started in 1888 to take over the works at Kingston, foresaw that there might be a higher standard required, and they provided against it by this clause:—

"Provided, nevertheless, that, if by reason of any future Act of Parliament, or any future requirements of the said Conservators applicable as aforesaid, it shall become necessary to make the effluent water as produced by any such process of the Company as aforesaid undergo any further or additional treatment before allowing the same to flow into the said river, and, if for that purpose any additional land and works or land or works shall become necessary to be provided, the same shall be provided by the Corporation at their own expense, and delivered up to the Company in the same manner in all respects as new or additional land and works are hereinafter by Clause 30 required to be provided and delivered up."

That is to say, it was provided for that there should be additional works if necessary. The Corporation have by a supplementary agreement with the company agreed to put down such additional works, and upon their agreeing to do that, the company have undertaken to guarantee to produce an effluent with a certain fixed quantity of albuminoid, which is understood to be satisfactory for that part of the river. The amount is 1¼ parts per 1,000,000; and they can easily do that because the results of experiments in filtration at Kingston have shown that the tank effluent passed over the filters produces an effluent which has an average of albuminoid of ·77. Well, that is almost half what is required. That is to say, the tank effluent which has an average of 2 is reduced by coke filtration to ·77. There is a result of an analysis made by Professor Dyer of the tank effluent, and the corresponding filtrate, which gives very much the same figures. This is another one of Dr. Dyer's, which gives rather different figures. You will see the albuminoid of both.

5178. (*Sir Michael Foster.*) Is it simply a coke filter?

—It is simply a coke filter worked on the intermittent principle.

5179. For what?—Three feet.

5180. Have you made any bacterial examination of the effluent?—We have not had it examined for bacteria, but I think it would be a very desirable thing if examinations could be conducted, perhaps by the Royal Commission on that subject. It is rather hard for us to examine everything bacterially, but certainly the action on this tank effluent in that filter seems to be just as good, if not better, than the action on one of those preliminary bacterial effluents.

5181. (*Mr. Killick.*) Do you know the rate at which the water is passed over at the top?—The actual per square yard?

5182. Per day?—Yes; per 24 hours about 310 gallons per square yard.

5183. (*Professor Ramsay.*) Do you know if any attempt has been made to ascertain whether the effluent would putrefy on being kept? The examination by Dr. Dyer of that effluent makes it appear that it is nitrified, and therefore is not liable to putrefaction. Do you happen to know whether without filtering through the coke bed it is liable to putrefy?—Well, we have not tried incubation experiments.

5184. That is what I meant?—We can only go by the general results of the albuminoids. I am sure the company would be very pleased if the Royal Commission would examine the effluents of the tanks, and the filter, and come to some conclusions themselves on this point.

5185. (*Sir Michael Foster.*) You are not at present negotiating with any town with the view of establishing your system?—Well, yes, we are negotiating, but it is rather difficult when everybody thinks of a bacterial process in some form or another. They seem to think they can do it cheaper in that way than they can through us. I think myself, of course, that they are mistaken, but it is rather difficult to persuade them so, and, perhaps, the bacterial in some form or other is undertaken by them with the view of getting rid of the sludge. Of course the very thing that we want is the sludge, and we utilise it, and take it out of the sewage, but their idea seems to be that it will disappear through the septic tank or through the bacterial filter. I may say one thing, that with regard to this filter we have had the filters working now for about two years, and the effluent from the tanks, as it does not contain any suspended matter, or at least any appreciable quantity is not likely to sludge up the filter in the same way as, for instance, in the case of a septic tank.

5186. You have not had to renew your filters at all during the two years?—Oh. no; we have had the capacity of the filters measured, and they come out like this. They are small filters; the original water capacity when first started—taking the coke one was 1,400 gallons, and during the period, one year—eighteen months; I have got the dates here—May, 1898, it was 1,400 gallons; in November, 1899, it was 1,295 gallons; and in June, 1900, 1,166 gallons. That is the reduction in capacity so far as we can ascertain. Well, that only amounts to 8 per cent. per annum, instead of 1 per cent. per week.

5187. (*Colonel Harding.*) What solids in suspension have you in the tank effluent that goes on to that filter?—So far as one can judge from analysis none, that is to say, the analysis does not give any appreciable quantity.

5188. It is quite brilliant, quite clear?—There are no solids in suspension, I think, in any of the analyses that have been given.

5189. Filtration necessarily, is comparatively easy?—Yes. that is one of the merits of the system, a combined system of precipitation with filtration.

5190. (*Major-General Carey.*) Was not the process tried for some time at Aylesbury?—Yes, it was.

5191. And they have given it up now, have they not?—They are not using it at the present moment, and if you want to know the reason I think the history of it is a very simple matter, if you would just allow me to refer to it, as you ask; I can tell you in brief. I may say that the secretary will refresh my memory if I am wrong in dates. The company first undertook the—perhaps Mr. Sillar will give you——

5192. (*Sir Michael Foster.*) Might I ask, did you propose the same, or similar terms to Aylesbury, that is to say, that you, upon a subsidy took all their sewage?—Yes; but the amount of the subsidy then was very much smaller than the amount that is charged now, because it was supposed at that time that it could be done cheaper, and it was before the company thoroughly understood the expense of the process. I think Mr. Sillar will agree with me in that. The Aylesbury people gave us a subsidy of about £250 a year the whole time, and during the whole time of that working they held money of ours as a guarantee that if any nuisance of any kind were brought against them we should pay the expense. They had also a quantity of land in case further treatment was necessary. They never had occasion, they never were called upon to use the land, never any complaints were made, and the consequence was when we retired from Aylesbury the money was returned to us, which they had held in case an action was raised against them. During the years we went there we were learning our lesson; we did not work as economically as we might, and the consequence was that there was a continual loss upon the working, and we have got a list of figures here; sometimes we have lost as much as £1,400 a year, and sometimes we have lost about £500 a year, and, therefore, when the Aylesbury people wished to know whether we would renew it we offered to continue it on the same terms provided they would raise their subsidy to cover our annual loss, so that, though we should not make any money out of them, we should not wish to lose any money by them. They thought they could do it more reasonably themselves, therefore we parted company with them, and removed our staff and our works to Kingston. The last year, I have got a memorandum here, we lost £500 a year by Aylesbury, so that the proposition we made to them was that, as they had already paid us £250, adding that £500 to it=£800, we would continue work for £800, but they preferred to try the experiment themselves, and they are trying it, but whether they will succeed or not is another question.

5193. (*Professor Ramsey.*) That is a considerable time ago?—Yes, about twelve years ago, when we went to Kingston, and removed our staff and our operations to Kingston.

5194. Aylesbury is not going in for this treatment now?—We worked for 14 years at Aylesbury, and got annual reports from them of their entire satisfaction with everything that was done. It was only a question of £ s. d. that we differed on at the end; since then they have offered and asked us to go back on those terms, but there has been such a great increase in the expense of coal and chemicals that we were not quite satisfied, and we were satisfied with Kingston. (*Mr. Archibald.*) I believe I may supplement what Mr. Sillar says, that if we had charged Aylesbury the subsidy at the same rate as we do at Kingston on the usual basis on which the company has now arrived at, that would be about the figure which would cover the whole thing, and render it possible to work it. (*Mr. Sillar.*) It should pay; it would not pay very much. (*Mr. Archibald.*) But then we would not lose money by it; very little above the figure which was offered at the end, and which would cover the loss in fact that was made there.

5195. (*Chairman.*) I suppose we have nothing to do but communicate with you, and you will let us come down and make our own investigation?—Certainly.—(*Mr. Sillar.*) We should like some of our representatives to be present in case information was wanted.

5196. Of course, the secretary will communicate with you beforehand?—(*Mr. Archibald.*) To let us know the time that you would come.

5197. Yes.—(*Mr. Sillar.*) I should wish the Commission to know that we have no secrets, and everything we are doing; we shall be perfectly open, our books will be open, everything we possess will be at your service; our object is that it should be known of what the process is capable and what it can do.

5198. (*Sir Michael Foster.*) Is your manure sold all over the country you say?—(*Mr. Archibald.*) Yes. (*Mr. Sillar.*) Not only all over the country, but quantities have been sent to the South of Europe, Barbadoes, and it has gone all over the world.

5199. (*Professor Ramsey.*) And do you get more demand for it than you can supply?—That depends; we would if we invited more: twice in my experience the demand exceeded the supply, to the injury of our market, and therefore we dare not. (*Mr. Sillar.*) I am quite sure if we increase our advertising we should not be able to supply the demand. Last year we sold a great deal more than we made, and we made such an inroad into our stocks that we were dangerously low.

5200. (*Sir Michael Foster.*) Is it used for any particular soil or any particular crops?—It is better on some soils than others. There is a great deal of clay in it. (*Mr. Archibald.*) These are pamphlets, which will show what

Mr. W. C. Sillar. 20 June 1900.

soils it is used on. (*Mr. Sillar.*) We have 24 annual statements, with the reports of farmers. I think we have brought three or four of them. If you ask about the rest, they are available, being the reports of the actual farmers who have actually used the native guano. (*Mr. Archibald.*) With the different results. We must show what the farmers think of it, and show the advantage to the qualities for which it is used. They are all labelled down here. (*Mr. Sillar.*) At the end of the year we send to every one who purchased it, asking them, on public grounds to give us an account of their experience of it, and they send us the reports which we print.

5201. (*Professor Ramsay.*) Just one other question; the sewage of Kingston, of course, is purely domestic sewage?—Yes.

5202. Do you profess to treat trade effluents or not, or deal with domestic sewage?—Well there are breweries and gas works in Kingston; so far it is not pure domestic sewage, but in Leeds and Bolton, and in other places where we were working, there was a great deal of coarse trade refuse, but we never found any difficulty; in fact I have an experience of that. Sir William Crookes, who took a great interest in us in those times, ascertained whether or not what we call our A B C was capable of dealing with the peculiar refuse from manufactories.

5203. (*Sir Michael Foster.*) What manufactories?—In Leeds it is everything woollen, and so he got samples of the sewage from everyone of them, and he found that the A B C process was capable of dealing with it. But when he had finished, and he had put all his samples into one reservoir, he found that their action was very peculiar; one counteracted the other, and the whole in combination was much more easily treated than they were individually, so he said there was not the slightest difficulty or danger in undertaking the treatment of any town, however complicated its sewage might be. (*Mr. Archibald.*) I may say I have a letter here from Mr. George Tatham, the chairman of the Council of Leeds, in which he refers to this very point. The sewage of Leeds, as is well known, is very difficult to treat on account of the waste products which are mixed with the ordinary commercial sewage, and he says——

5204. What date is that?—This is 29th February, 1876. And also he says here in another statement: "I, George Tatham, of Leeds, in the county of York, an alderman and chairman of the Streets and Sewerage Committee of the Council of the said borough, at the request of the Native Guano Company, hereby certify—

"1. That the town of Leeds has disinfected a part of the sewage of the town, and are about completing works to disinfect the whole of the sewage by means of the 'A B C' process.

"2. That the effluent water produced by the process is sufficiently pure to be allowed to flow into the river with the assent of the authorities.

"3. That the whole of the process, including the preparation of the native guano, is performed without offensive odour or nuisance.

"(Signed) GEORGE TATHAM.

"September 22nd, 1873."

5205. (*Colonel Harding.*) That is the opinion of the chairman of the committee?—Yes.

5206. (*Sir Michael Foster.*) Have you had any proposals from America to make use of your process?—No, I do not think so.

(*Chairman.*) Thank you very much. I do not think we need detain you any longer.

Mr. HUGO WOLLHEIM, called; and Examined.

THE "AMINES" PROCESS.

Mr. H. Wollheim.

(1) Description.—Improved method of treating and disposing of sewage, including any liquid from any factory or manufacturing process. Patent No. 15321/88.

My invention relates to a new gaseous reagent, to which the name "Aminol" has been given, and which has been found to be antagonistic to the existence and propagation of every species of bacteria occurring in sewage and other foul or waste liquids. It is produced by the action of alkalies, such as lime, on certain organic bases belonging to the chemical group of "amines," *e.g.*, tri-methyl-amine $(C.H.^3)_3$ N., and which are contained in many objects occurring in Nature, and also in some waste products. In the "Amines" process the reagent is produced by mixing with milk of lime a small quantity of the waste brine from the curing of herrings, herring brine being at present the cheapest and most abundant waste product available, and which will yield the organic bases referred to in sufficient quantity for all requirements. The process is applied in the same manner as precipitation processes generally, viz., by adding the said mixture of milk of lime and herring brine to the sewage during its flowing to the settling tanks; it can therefore be applied at the very shortest notice, and without any additional plant at any existing works, where there is proper tank accommodation.

(2) Advantages.—The main and distinctive advantage which I claim for my process, and from which other advantages follow as a matter of course, is: that it accomplishes complete "sterilisation." The "Amines" effluent is, therefore, non-putrescible; it cannot pollute or contaminate watercourses or subsoil water, nor can it, when used for irrigation, spread infection by causing germs of disease to adhere to roots or leaves of plants. The "Amines" sludge is also non-putrescible, even under prolonged exposure to the most varying climatic conditions. This feature opens up avenues for its utilisation which are closed to sludges liable to putrefactive change; whatever it possesses of fertilising properties—and they are not inconsiderable, since it contains all the phosphates of the sewage treated and a considerable portion of its ammonia—is not, as is the case with putrescible sludges, wasted by fermentation.

(3). Grounds upon which Advantages Claimed are Supported.—My claims stand fully corroborated by the results of exhaustive investigations carried out by Dr. E. Klein, F.R.S., by Major Chas. E. Cassal, F.I.C., public analyst, and by other eminent and independent experts. From the several published official reports in my possession, full copies of which can be furnished if desired, I give the following extracts, and I append a complete chemical analysis of the "Amines" effluent (from the trial at Salford referred to under the head of "Cost"), and, further, a few extracts from testimonials regarding the practical results obtained in farming and gardening with the sludge (pressed cake) produced by the Wimbledon authority in the treatment of their sewage with the "Amines" process (the quantity of sludge cake used in the Essex trials amounted to many barge loads).

Extracts:

From Klein's report, dated February 15th, 1889, on the results of experiments at the Canning Town Sewage Works (West Ham):—

"Sample No. 1 (sewage) contained 2,400,000 organisms per cub. cent.; sample No. 4 (effluent) contained none. As regards sample No. 4 (effluent), this, containing no demonstrable micro-organisms, could, therefore, on its discharge into a river, cause no increase of the microbes already present in such river."

From Klein's report, dated July 22nd, 1889, on the results of experiments at the Wimbledon Sewage Works:

"Sample No. 1 (crude sewage). The number of microbes in it averaged 768,000 per cub. cent. Sample No. 3 (effluent).—This had also been divided into two parts, one of which was kept in the glass-stoppered bottle, the other transferred to a bottle plugged only with sterile cotton wool. Both divisions were subjected to three consecutive tests by gelatine plates, viz., after twenty-four hours, after three days, and after six days. Every one of these plates showed an entire absence of microbes; the effluent must, therefore, be pronounced to be sterile. . . . . In conclusion I would say that the powerful antiseptic and disinfectant properties of your treatment, as shown by its effect upon the organisms present in sewage, leads me to suggest the importance of carrying the investigation a step further, viz., to determine its effect on specific micro-organisms, such as, for instance, bacillus anthracis, the cholera comma bacillus, the typhoid bacillus, the pneumonia bacillus, and others."

From Klein's report, dated May 16th, 1890, on special experiments on cholera microbes:—

"The result of the experiments of the "Amines" treatment of Koch's cholera microbe was this: That by that treatment the life of the microbe is completely destroyed."

From Klein's report, dated August 5th, 1891, on samples from the trial at the Mode Wheel Sewage Works, Salford:

"After one week's incubation the following was found: Sample No. 1 (filtered effluent) contained innumerable colonies, except a dozen or so of largish white colonies, all the others (uncountable) were of one kind—small, grey, non-liquefying; compared with sample No. 2 (unfiltered effluent), I am of opinion that the filter has added to the effluent an unaccountable number of bacteria of one and the same species.

"Sample No. 2 (unfiltered effluent) contained ten colonies, amongst them two moulds, for one whole cubic centimetre; therefore, only eight bacteria being present, it may justly be said that the effluent was practically sterile.

"Sample No. 3 (river Irwell water above the intake) contained on average 80 to 100 thousand bacteria per 1 c.c.

"Sample No. 4 (Pendleton sewage) contained above ten millions per 1 c.c."

From Cassal's report, dated March 15th, 1890, on the results of his investigations carried out at various times and places:—

"I have undertaken an investigation of the 'Amines' process for the treatment of sewage. The process has been repeatedly worked in my presence and under my control at the Wimbledon Sewage Farm and elsewhere, and from the results, which have been obtained under these circumstances, and those which I have arrived at up to the present time upon the smaller scale in my laboratories, I am in a position to report generally upon the process. The process essentially consists in the treatment of sewage with a precipitant composed of milk of lime and herring brine, or of milk of lime with certain organic bases known to be present in herring brine, by thoroughly agitating this 'precipitant' (added in certain proportions) with the sewage, and allowing the sludge produced to settle in tanks. The scope of my investigation has been to determine whether by the application of this process the following results were obtained:—

"1. Clarification, rapid subsidence, and removal of offensive odour.

"2. Removal of a substantial part of the organic matter contained in the sewage.

"3. The production of an effluent free from micro-organisms, or 'sterile,' and consequently not liable to putrefaction, and in which this condition was maintained for any lengthened period, and whose degree of alkalinity was within the limit suggested by the Rivers Pollution Commission.

"4. The production of a non-putrescible sludge. . . . . .

"As the result of my examination of the 'Amines' process, I consider that the points set forth in this report have been fully established. . . . I am of opinion that the process is likely to prove of considerable value. The great importance of the results stated should be sufficiently obvious, and I consider, further, that in the public interest every facility should be given for trying it on the largest possible scale."

From Cassal's report, dated August 17th, 1891, on samples from the trial at the Mode Wheel Sewage Works, Salford:—

"The results of my investigations into the 'Amines' process have been reported from time to time, and the analytical data now obtained serve to confirm the analyses made and the conclusions arrived at by me upon previous occasions. Clarification and the removal of a substantial part of the organic matter have been satisfactorily effected, and no objection can possibly be taken to the alkalinities of the effluents. The analysis of the effluent after filtration (B) shows that while the total solid matter, the chlorine, and the alkalinity have been lowered by the filtration process (compare with analysis of Effluent A), the amount of organic matter in solution has been but slightly lowered, and I therefore do not consider that the effluent has been appreciably improved by the particular form of filtration to which it was subjected. Inasmuch as the 'Amines' process produces a 'sterile' effluent, there is no special advantage to be attained by the application of any ordinary filtration to it—a fact which I have pointed out and dealt with more fully in a previous report. Dr. Klein having undertaken the bacteriological examination of these samples, I have not made any experiments in this direction. I may mention that the samples of effluent have remained up to the present date, undecomposed and inoffensive."

ANALYTICAL REPROT on Two Samples of Sewage and One Sample of Water from the RIVER IRWELL taken at SALFORD, and received from the "Amines" Sindicate on 29th July 1891.

NAME OF SAMPLE.	1. PENDLETON SEWAGE 11 A.M. 27-7-91.	2. SALFORD SEWAGE. 11 A.M. 27-7-91.	3. RIVER IRWELL WATER. Above outfall, 11 A.M. 27-7-91.
Appearance in Porcelain Vessel, one inch in depth.	Very Turbid. Opaque. Deep bluish-black colour.	Very Turbid. Bluish-black colour.	Somewhat Turbid. Yellowish-brown colour.
Solid Matters, Unfiltered Samples — Total	249·2	124·4	77·6 parts per hundred thousand
Solid Matters, Unfiltered Samples — Volatile	126·4	42·2	20·0 " " "
Solid Matters, Unfiltered Samples — Fixed	122·8	82·2	57·6 " " "
Solid Matters, Filtered Samples — Total	74·8	116·8	66·0 " " "
Solid Matters, Filtered Samples — Volatile	37·2	28·4	17·6 " " "
Solid Matters, Filtered Samples — Fixed	37·6	88·4	48·4 " " "
Total Suspended Matter	174·4	7·6	11·6 " " "
Chlorine as Chlorides	14·0	39·5	11·5 " " "
Equivalent to Common Salt	23·06	65·05	18·94 " " "
Nitrogen as Nitrates	0·0	0·0	0·0 " " "
Saline or Free Ammonia	51·4	18·04	7·61 parts per million.
Organic or Albumenoid Ammonia	22·8	4·64	3·28 " "
Oxygen absorbed from Permanganate—			
a. 15 minutes 30° C.	171·34	41·79	17·31 " "
b. 3 hours 30° C.	277·6	75·82	37·31 " "

Laboratory, Mount Street, London, W., 17*th August* 1891. CHARLES E. CASSAL.

Mr. H. Wollheim.

20 June 1900.

ANALYTICAL REPORT on Two Samples of "Amines" Effluent taken at S .

Received from the "Amines" Syndicate on 29th July, 1891.

NAME OF SAMPLE.	A. UNFILTERED EFFLUENT. 1.30 P.M. 27-7-91.	B. FILTERED EFFLUENT. 1.30 P.M. 27-7-91.
Appearance in Porcelain Vessel, one inch in depth.	Clear and Bright. Colourless.	Clear and Bright. Colourless.
Total Solid Matters	86·8	66·0 parts per hundred thousand.
a. Volatile (loss on ignition)	27·8	18·4 " " "
b Fixed	59·0	47·6 " " "
Chlorine as Chlorides	26·5	22·0 " " "
Equivalent to Common Salt	43·64	36·23 " " "
Nitrogen as Nitrates	0·0	0·0 " " "
Saline or Free Ammonia	24·1	24·1 parts per million.
Organic or Albumenoid Ammonia	3·64	3·0 " "
Oxygen absorbed from Permanganate :—		
a. 15 minutes 30° C.	12·53	10·29 " "
b. 3 hours 30° C.	34·47	27·46 " "
Alkalinity as CaO.	14·0	5·6 parts per hundred thousand.

Laboratory, Mount Street, London, W., 17*th August*, 1891. CHARLES E. CASSAL.

From the report for 1889-90 to the Local Government Board, by Evelyn Pocklington, Esq., M.R.C.S. (Medical Officer of Health to the Wimbledon Local Board) :—

> "Sewage Treatment.—For more than six months during the year the sewage has been treated with a mixture of two tons of lime and one-fifth ton of herring-brine, per million gallons of sewage treated, known as the 'Amines' process, which has proved a great success. The process has a marked effect in rendering inodorous all the products of the treatment. The crops irrigated with the effluent are quite as luxurious as those in the case of previous treatment, while the cost of such treatment is not in excess of that of lime and alumina. The men employed in cleaning the tanks, pumps, wells, etc., find a great benefit since the process has been adopted.

From a paper read before the Civil and Mechanical Engineer's Society, on the 5th February, 1890, by C. H. Cooper, Esq., Assistant (now Chief) Engineer to the Wimbledon Local Board :—

> "In the 'Amines' process a mixture of lime and an 'Amine' (ammonia compound) is added to the sewage before it enters the settling tanks in which the sludge is deposited, the 'amine' being supplied with other substances in the form of herring brine. The proportions in which these re-agents are added average 2½ tons of lime and one-fifth ton of brine to a million gallons of sewage. By the addition of so large an amount of lime, the glutinous nature of the sludge precipitated is destroyed, so that it can be pressed without a further addition of lime. A layer of this sludge nine inches deep lost 75 per cent. of its bulk while exposed in a pit for three weeks during September last. The cloths used in the filter-presses last longer when pressing "amines" sludge than in the case of ordinary sludge, to which hot lime has been added. The clarification of the 'effluent' in this process is remarkable, for in almost every instance within 25 minutes after the sewage is admitted into the tanks, the supernatant liquid from which the sludge has precipitated is transparent to a depth of nearly six feet. A great point in the 'Amines' process is the absence of unpleasant smell from the tanks, effluent, sludge, or even press liquor. These products have been kept for months, and exposed to most trying tests without any sign of decomposition or bad smell. Many persons have thought that the antiseptic properties of the effluent and sludge would render them injurious if applied to growing crops, but after a trial of four months on the Wimbledon sewage farm no bad effects have been noticed."

Cost.—Neither the initial cost nor the working expenses can possibly suffer any increase by the addition of the herring brine to the milk of lime. On the other hand it is plausible that a saving can be affected—

(*a*) In Tank Space.—On account of the rapidity of the clarification, which favours the working of the process on the continuous overflow system.

(*b*) In Labour.—On account of the inoffensive character of the sludge, which obviates the necessity of frequent removals.

(*c*) In Filtering or Irrigating Area.—On account of the entire freedom of the effluent from any suspended matter whatsoever.

As to the remaining item, which goes to make up the cost of the process (apart from a possible return from utilization of its products), viz., the quantities and cost of the materials used, that depends, of course on the nature of the sewage to be treated, and on the prices of materials ruling in the respective localities. In this respect I cannot give a clearer indication than by referring to the two following very conclusive experiences with the process in actual extensive and prolonged working, viz., the two weeks' trial at Salford, and the permanent application at Wimbledon. These two instances represent a wide difference in the nature of the sewages, and also in the ruling price of lime (that of the herring brine being practically equal in both).

Salford.—The trial of the "Amines" process took place in 1891, in midsummer. The entire flow, about 7,000,000 gallons daily, was treated in continuity for two weeks, ending on the 27th July. The nature of the sewage is thus fitly described on page 60 of a printed report issued by the Corporation in January, 1891 :—

> "When the two sewages (that from Salford and that from Pendleton) are mixed together in about the proportion in which they normally flow into the Mode Wheel Works, they constitute one of the worst combinations which a corporation could have to deal with."

The following quantity figures are those officially given by the Borough Engineer, confirmed by the referee chemist to the Corporation, and accepted by me, as closely agreeing with the determinations of my own engineer. They are interesting also with regard to the quantity of sludge produced. The cost of materials used figures out at £1 15s. per 1,000,000 gallons = a trifle over ⅝d. per 1,000 gallons, lime being 10s., and herring brine 50s. per ton.

The total quantity of :—

= 22½ grains per gallon	Sewage treated was 84,623,300 gallons.
= 4 " "	Quicklime used was 120 tons 13 cwts. 3 qrs.
= 0·57 per cent. "	Herring brine used was 21 tons 10 cwts. 3 qrs
	Sludge produced was 2,816 cubic yards, by measurement.
about 26 tons per 1,000,000 gallons.	Wet sludge produced was 2,211 tons 3 cwts. by weight.

Dried at 212° F. (the moisture being about 92 per cent.), this would give about 177 tons dried sludge, which as pressed cake (with 50 per cent. moisture) means 354 tons, or about 4½ tons per 1,000,000 gallons sewage treated.

Wimbledon.—(Sewage mostly domestic; average daily dry weather flow about 600,000 gallons.) Here

the process was adopted in its entirety in 1889, and remained in operation with officially acknowledged unvarying success till the end of 893. The sewage farm, comprising 73 acres, was irrigated with the tank effluent and manured with the sludge (pressed cake). The official report of the Urban District Council for 1890-1 says:—

"The average cost of chemical treatment during the year amounted to 38s. 6d. per million gallons."

I shall refrain here from enlarging upon the question whether in the "Amines" process the cost would or could be reduced by profitable utilization of the sludge. I will content myself with quoting the following few authenticated results of practical tests:—

EXTRACTS FROM TESTIMONIALS AS TO THE VALUE OF "AMINES" MANURE.

(Filter-Pressed Sludge Cake, from Wimbledon.)

From a letter of Mr. J. Ambrose, late London County Councillor, on results obtained at his farm, East Hanningfield, Essex:—

"I was quite satisfied with the sludge as a manure. The wheat turned out seven sacks to the acre, while others around had between four and five; and the clover, after wheat, looks splendid."

In a further letter Mr. Ambrose says:—

"The wheat crop on the whole this year is disappointing, but the yield under the sludge manure was five quarters per acre, as against two and a half quarters per acre average on the other parts of the field—or just as much again."

Mr. F. Knight, Farmer, Melbourne, near Derby:—

"The 'Amines' Manure you had supplied me with this spring has answered well, especially for swedes. Many of my neighbours say they are the best they have seen this season."

Mr. Charles Hulse, Market Gardener, Derby:—

"I have tried the manure on all kinds of vegetables and greens, and have found it answered well."

Mr. Charles Hannam, Manor Farm, Burton, Dorset:

"I have very good pieces of roots grown by your manure although the season has been a bad one."

F. Ede, Esq., jun., Balham:—

"Our crops of spinach, peas, beans, and beet have been greatly benefited by it, no other having been used on the land, which was in a very poor condition."

The following are the places where the process is at present in operation and the periods during which the licences for its use have been in force. The scale on which it is being worked there is a moderate one:—

Estate of the Duke of Westminster, K.G.:	
Installation at Eaton Hall -	since Feb. 1894
„ „ Eccleston -	
Estate of Col. Cornwallis-West, M.P.:	
Installation at Milford Haven. -	„ Aug. 1896.
Estate of Col. C. W. Bell, J.P.:	
Installation at East Grinstead	„ July 1894.
Sewage Works of the Warwick Sanitary Authority.:	
Installation at Kineton - -	„ June 1899.

I am willing to demonstrate the merits of the "Amines" process by experiment before the Royal Commission on Sewage Disposal.

HUGO WOLLHEIM.

86, Elsham Road, Kensington, W.
London, 22nd May, 1900.

5207. (*Chairman.*) You are Mr. Hugo Wollheim, and you come to speak about the "Amines" process. Now, I do not think the Commission are likely to ask you very much. We have all read your statement, and that will be put upon our Minutes; but we understand that you invite us to examine the results of your system for ourselves, and that we shall be glad to do?—Yes.

5208. Would you tell us where we should be best able to examine them?—I mention in my statement the places where it is in operation, but they are rather far from here, and I have been thinking that if you should wish to examine it perhaps I could arrange an experiment near London—perhaps at the place where it has been in operation for so many years—at Wimbledon. I believe I could get the permission from the authority to show it to you on any special occasion. Or you would perhaps be satisfied with a small experiment before you here, say, on 10 gallons, or any other suitable scale.

5209. Is it working regularly now, say, at the sewage works of the Warwick Sanitary Authority; are they in regular work?—Yes, they are continually working it.

5210. They are continually at work?—Yes, also at the Duke of Westminster's estate.

5211. And I should think probably the works of the Warwick Sanitary Authority would be the best place for us to send to?—It is rather on a small scale there.

5212. On a small scale?—Yes.

5213. Where is it on the largest scale?—The installation at Kineton near Warwick is the largest at present.

5214. Yes, that is the one; that is where we propose to go?—I wish to call your attention to one fact that I think it would be more satisfactory to you if you could see me working it. I think it would be fairer to the process also if I could show you how it is properly to be worked, because——

5215. (*Colonel Harding.*) Is not some reference made to important experiments at Salford, can the witness tell us. Do you not make some reference to experiments which have taken place at Salford?—1891, at Salford.

5216. On a large scale?—The whole Salford sewage, about 7,000,000 gallons daily.

5217. Has that process been continued at Salford?—Oh, no.

5218. Can you tell us why it was discontinued?—Salford you must be aware tried almost every process; at any rate all the most prominent ones, and they have not adopted any of them.

5219. The natural inference is if they gave it up it was not a success?—I do not believe that is the natural inference because they have not adopted any process, and are still continuing the old lime process.

5220. Can you tell us anything about these experiments at Salford on a large scale with your system?—You have a full description of them in my statement.

5221. You consider them satisfactory?—Well, they were very satisfactory, as Dr. Klein, who reported on them, says, but as to whether an authority properly refuses the adoption of the process or not, I am not able to say, you know I can only lay before you the evidence of its success by very eminent experts, and as to the reasons why an authority does not adopt the process I cannot say.

5222. What is it that you claim to accomplish; is it sterilization?—Sterilization.

5223. Or is it the use of a precipitant?—Sterilization is practically the claim, and I believe from that the other advantages claimed follow naturally.

5224. But the use of these materials produces precipitation?—Produces precipitation. It is a precipitation process with milk of lime, to which has been added a small quantity of herring brine, and there is a principle in that herring brine which acts as a steriliser.

5225. Do you think that sterilization at that stage is a good thing?—I think it is a proper thing.

5226. The mere precipitation would require some subsequent filtration?—It would. It would require some subsequent treatment because the mere lime precipitation does not produce sterility and prevent putrefaction in consequence.

5227. Then what is your object in sterilising at that stage, because you interfere, do you not, with the filtration action later if it is to be filtered?—I did not filter in Salford except to show that the filter was not necessary. I should not require filtration as far as I am concerned, if it was not that the Local Government Board urges that the authorities may not carry out a process properly, and that for that reason land or filtration is required as a safeguard.

5228. And though you do not think it necessary other people do?—I do not think it is necessary for this reason: There is no object to be gained by filtration of an effluent entirely free from suspended matter and sterile.

5229. Have you considered the possibility or steriliss-

Mr. H. Wollheim.

20 June 1900.

ing filtered effluents by your process?—I can sterilise them, yes, certainly; but it would be absurd to sterilise them by this means, to add lime to them you know; they can be sterilised in some other way, certainly.

5230. You do not suggest that for sterilization after filtration your system is of any service?—Oh, no.

5231. (*Sir Michael Foster.*) Could you speak of a particular constituent in the herring brine which is the steriliser—which kills the bacteria?—Yes, I am alluding to "Tri-methyl-Amine."

5232. You regard that as germicidal?—No, I do not claim that as the sterilizing reagent; I claim a new substance produced by the action of the lime on the "Tri-methyl-Amine."

5233. Has that been worked out?—Oh, yes.

5234. What is the nature of the product?—I could not tell you the formula; it has not yet been isolated.

5235. So that may be used as a bactericidal agent alone, this product of the action of lime on "Tri-methyl-Amine"?—Yes.

5236. That produces a substance which kills all bacteria?—Yes, that is it; that is my claim.

5237. If that substance is isolated, that substance might be added to all effluents with the view of killing bacteria?—It might be added without adding the lime; you can produce the same effect with potash, for instance, and by acting with potash on "Tri-methyl-Amine," you might produce a reagent which would sterilise without requiring any lime. I use lime because I want to precipitate, and as I must clarify I must have the lime, and the lime acts at the same time as producer of that new substance.

5238. Your system is at work at Kineton?—At Kineton, yes.

5239. But it does not work well of itself when you are away?—Oh, I do not say that, but I do not guarantee that an authority would always apply properly; I do not think it is fair to me to judge my process, except when I produce it or supervise it.

5240. Is any bacteriological examination of the effluent there being made now?—No, not at Kineton, no.

5241. Has it every been made there?—It has only been in operation a little while there.

5242. No, but to see if the system was working satisfactorily?—I have their letters asknowledging that it is very satisfactory.

5243. Yes, but was there a bacteriological examination of the effluent?—That I am not really concerned with. They have seen the system elsewhere, and heard of it; they have taken a license; I have given them a license; that is the way I operate. I sent my son, who is an engineer, to install it, and show it to them, and further than that I am not concerned with it.

5244. How many samples did Dr. Klein examine?—Oh, he has examined it repeatedly—four or five times.

5245. (*Major-General Carey.*) What proportion of lime do you use?—Well, on the large scale the best I have done so far is about 22½ grains to the gallon at Salford. that is something under 1½ tons per million gallons.

5246. And what is the volume of sludge produced?—The volume of sludge was a little over a half per cent.; fifty-seven one-hundredths per cent. it turned out. You will find the figures on the statement which I have submitted, and here I can give it to you exactly. These figures are from the official report of the Salford Authority; the total quantity of sludge figures out 0·57 per cent., or about 26 tons per million gallons treated.

5247. (*Professor Ramsay.*) Do you get a price for the sludge; can you sell the sludge?—It has been sold, yes; I have sold it; I have sent barge loads of it to a member of the County Council, who tried it on his farm in Essex. I find, of course, there is some difficulty in selling the sludge in some localities, and the freight—the railway freight is very much against it. If that could be properly reduced it might find a much larger field. And then, again, most authorities are satisfied to produce it in the form of a cake, a pressed cake; whilst if it was further treated, that is powdered and bagged, it would have a much larger field; you could store it, you could send it to long distances. I would suggest that perhaps it might suit the Commission to have me make a special experiment before them on any scale that they would think sufficient.

5248. (*Chairman.*) Dr. Klein's examinations took place in 1889, did they not; the samples he took he took in 1889, did he not?—In 1889, and again at Salford in 1891. I think that is the latest.

5249. I see the sample he took was from the Canning Town sewage works at West Ham?—That was the first one.

5250. Are those going on still?—Oh, no.

5251. His second sample was apparently from the Wimbledon Sewage Works?—Yes, from the Wimbledon Sewage Works.

5252. Are they going on still?—They have stopped the process since 1893. It was there from 1889 to 1893.

5253. And then do you know why they have stopped it?—Yes. You have got the acknowledgment of the authorities on record that it worked highly satisfactorily, but the surveyor conceived the idea that he could do as well and save a couple of hundred pounds a year by adopting the lime and copperas process, you know. Well, he has failed to substantiate his claim to this day. I have got papers here from which I could show you that the chemical treatment of the Wimbledon sewage has since then been practically at the same cost every year; there was no saving on it.

5254. And have you had your filtered effluent bacteriologically examined since the year 1891?—Yes, but not after 1893. I have some reports, I believe, as late as 1893.

5255. Then, in fact, none of the effluents where your system is at work now have ever been examined from a bacteriological point of view?—I do not know whether the Duke of Westminster has had any investigation on his own account; the sterilizing effect has long since been generally admitted.

5256. But you do not yourself know of any late bacteriological examination?—I do not know of any late bacteriological examination.

5257. I think we need not detain you any longer now. The best thing would be that we should communicate with you whenever we are ready to send our representative down to Kineton?—You propose to go to Kineton, do you?

5258. Well, we propose to send a representative?—You would not prefer an experiment that I make to you; do you not think that it would have a double advantage? It would be more conclusive, and it could be witnessed by the whole Commission.

5259. We do not want special experiments at all?—But I mean if the entire Commission could see a treatment of the Wimbledon sewage, for instance, on any day suiting them, would not that be much more advantageous?

5260. Oh, no; we should send our representative to Kineton?—Very well.

TWENTIETH DAY.

SEWAGE WORKS, LEEDS.

Tuesday, 24th July, 1900.

PRESENT:

Mr. THOMAS WILLIAM KILLICK (in the Chair).

Professor WILLIAM RAMSAY, F.R.S.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. CHARLES PHILIP COTTON.
Mr. WILLIAM HENRY POWER, F.R.S.

Mr. F. J. WILLIS, *Secretary*.

Mr. W. H. HARRISON, B.Sc., Chemist to the Leeds Sewage Committee, called in; and Examined.

Mr. W. H. Harrison, B.Sc. — 24 July 1900.

5260*. (*Chairman.*) You have made some experiments, I believe, Mr. Harrison, with regard to liquor from some neighbouring works containing a large quantity of iron?—Yes.

5261. Can you tell us what these are?—It was a question of the precipitation of iron by lime, the amount of lime needed, and the utility of the product produced.

5262. And can you give us the conclusion at which you have arrived?—I find that this particular iron liquor, which contains large quantities of ferrous chloride and ferrous sulphate, together with sodium sulphate, needed about an amount of lime equal to the weight of the iron actually present to precipitate, 75 per cent. of the latter. That more iron was not removed was due to the formation of calcium sulphate by the action of the lime upon the sodium sulphate causing a portion of the lime to that extent to be wasted. It was found that the flocculent residue on drying could be utilised for the removal of sulphur from crude illuminating gas. It acted as well, if not better than the ordinary dry oxide.

5263. (*Professor Ramsay.*) Of iron?—Yes; which had formerly been used.

5264. (*Colonel Harding.*) I should like Mr. Harrison to tell us, if he can, what quantity per gallon of lime he found necessary to produce adequate settlements?—I should think about one gallon of the refuse liquor contained about 3,000 grains of metallic iron in solution, and this would need about 3,000 grains of lime to remove 75 per cent.

5265. (*Professor Ramsay.*) What is the percentage?—It is about 2·8 tons in 15,000 gallons, *i.e.*, the day's output. I could not give the percentage without calculating it out—about 4·2 per cent.

5266. Could that be done?—It could be done.

5267. Did you find the sulphate of lime came down first in the precipitate?—Not altogether; it did to a certain extent.

5268. When you speak of the flocculent iron do you mean that you removed the sulphate of soda first?—No.

5269. You left the whole thing together?—I left the whole thing together. The method I used was to make a very strong milk of lime; get the lime in as finely divided a condition as possible, and to mix that with the strong iron liquor as got direct from Nicholsons, and the sludge produced was turned direct into a small lagoon. There was no settlement attempted. I found that the sludge produced was quite thick enough to turn into a lagoon without any settlement being required, and that with a well constructed lagoon the time it took to dry to a spadeable condition was very short—about two hours for a layer of the sludge a foot and a-half in thickness.

5270. What results have they got in the gas works from it?—Well, the experiments are not completed yet, but so far they have found that it does not absorb all the sulphur. There is a small amount which comes through, and which will have to be removed by lime, but probably 99 per cent. of the sulphur is removed at first. This gradually gets lower and lower until probably about 60 is removed, and then the oxide of iron is exposed to the air, to revivify, as they call it; they then use it over again.

5271. In their present process, do they require to take out their last trace of sulphur, or is that sufficient to do it?—Yes; I think that the last traces are removed also.

5272. They can without lime?—I believe they can remove more by means of the lime than they can with the iron. In the case of the iron it is merely a trace that goes through at first.

5273. (*Colonel Harding.*) Have you tried any experimental treatment with lime of this effluent diluted?—No; I did not think it was practicable, as it needed diluting to such an extent to get the whole of the iron precipitated when using a minimum of lime, and at the same time this procedure necessitated the use of settling tanks. I found it a far quicker method to mix the iron direct with the lime, and turn the whole into a sludge lagoon, suitably constructed.

5274. And in that case no effluent resulted at all; the result was a sludge?—An effluent resulted free from suspended matter.

5275. Oh, there was an effluent?—Yes, but, of course, very little in proportion to the amount of liquid originally taken.

5276. The great bulk of it was sludge?—Yes.

5277. (*Professor Ramsay.*) You have not tried any experiments on evaporation for the crystals, I think?—No; I have not. I find that the liquor, as sent to us direct, on standing deposits sodium sulphate without any evaporation at all.

5278. So that the first crop of crystals would be sodium sulphate?—Yes.

5279. The next crop of crystals would probably be sodium ferrous sulphate?—Yes.

5280. And then chloride of iron remains in solution?—Yes.

5281. Do you know if there is any market for the sodium ferrous sulphate?—I never heard of one.

5282-3. There would be, I should think. It is a very pretty salt which does not change its condition at all in the air——

(*Colonel Harding.*) But would not its value be prejudiced by admixture with other salts?

(*Professor Ramsay.*) No, because what people buy these iron salts for is the amount of iron they contain, and they pay for those salts in proportion to the amount of iron they contain of the ferrous kind. It is an advantage to buy these sulphates for ink making, or for Prussian blue, so I should think there would be a very fair market for this substance?—Well, there is a good market in the leather trade for iron salt, for the blacking of leather.

5284. That means making ink, in point of fact?—Yes.

5285. (*Colonel Harding.*) Mr. Harrison, it has been suggested that the sludge which you settle in that way, was in fact, iron ore. Did you ever ask anyone whether it had any value for the extraction of the iron?—I am afraid it would not have much value, it is too finely divided.

5286. (*Professor Ramsay.*) And too much sulphur?—And too much sulphur, yes, and it would be no use in the blast furnaces.

Mr. W. H. Harrison, B.Sc.

24 July 1900.

5287. (*Colonel Harding.*) And I think the conclusion you came to was that there would probably be no advantage to the city of Leeds, if it had to treat this effluent, and to pay the cost of the treatment; that it would be better to receive it into the sewers, and put up with the difficulties here?—Certainly.

5288. Did you try any other precipitant than lime?—Yes.

5289. Tell us?—I have precipitated the iron by the use of potassium permanganate, and in neutral solution.

5290. Well, with what results?—I found that iron was precipitated as an insoluble basic salt which was readily removed by sedimentation. The cost, however, was enormous, being somewhere about £140 for the treatment of 15,000 gallons per day.

5291. Then did you make any estimate of the cost of treatment by lime, assuming the results are not saleable?—Yes. It would cost roughly speaking anywhere between £3 and £5.

5292. Per what?—That is in lime alone.

5293. Per day?—Yes.

5294. That is simply the cost of the lime?—Yes, that is to remove practically the whole of the iron.

5295. Then with the volume of iron liquor produced by Messrs. Nicholsons, what would be about the amount of sludge per day that would be produced?—About 15,000 gallons, and, adding to that the milk of lime, say, 16,000 gallons of sludge per day.

5296. How many tons?—About 75 tons.

5297. (*Professor Ramsay.*) About 75 tons, well, that is a serious amount of sludge per day to deal with by a private firm. That could not be taken up by the gas works?—Oh, yes; it would not supply the gas works.

5298. (*Colonel Harding.*) Have you had a definite report from the gas works?—I have not, they have not finished the experiments yet.

5299. You have not had an official report?—No.

5300. You have heard indirectly that it was giving fair results?—Yes, I have. So far, it has given very fair results. I have also tried to make it into paint, but it would only give a very inferior paint, owing to the calcium sulphate contained. It would be on a par with that well adulterated oxide paint that is sold now.

5301. Then, Mr. Harrison, another question about iron liquors proceeding from pickling; the difficulty there is very much less than in this case, because I suppose the liquor contains only ferrous sulphate, and that can be easily recovered in the crystalline form by evaporation?—Yes.

5302. And such crystals can be sold?—That is so.

5303. At a price probably to repay the cost of treatment?—I could not say with any degree of certainty.

5304. (*Professor Ramsay.*) Have you a quantitative analysis of this?—Yes.

5305. What are the proportions of ferrous sulphate and ferrous chloride?—I have here that 10 cc. of that liquor contains ·77 grammes of SO_4.

5306. Then the iron?—The iron, one gallon contains 2929 grains of metallic iron, or 10 cc. contains ·419 grams of iron.

5307. And the ferrous chloride; the amount of ferrous chloride?—I have not estimated the chloride.

5308. (*Colonel Harding.*) Did you estimate what was about the measure in metallic iron of what came down in the sewers of Leeds as iron liquor?—Yes, from 4 to 5 tons on an average comes down per day; and the particular iron liquor we are speaking about now usually turns out about 3 tons a day.

(*Professor Boyce.*) May I ask Colonel Harding if he thinks there is an objection to the iron going on the Whittaker bed?

(*Colonel Harding.*) The iron is a difficulty undoubtedly with any filter bed.

(*Professor Boyce.*) But on the Whittaker bed where it gets oxidised?

(*Colonel Harding.*) Oh! on the Whittaker bed?

(*Professor Boyce.*) Yes, on the Whittaker bed.

(*Colonel Harding.*) We have not found any serious inconvenience on the bed itself, but as you yourself would see part of the solids coming away from the bed consist of iron.

(*Professor Boyce.*) Quite, but may I not point out that that iron may have a very beneficial effect in throwing down those very solids that we seek in that effluent. That is really acting as a self-purifying apparatus, the Pielke Tower, the old system of throwing down the iron.

(*Colonel Harding.*) That may be a point, that might be investigated.

(*Professor Boyce.*) I do not know what Professor Ramsay thinks?

(*Professor Ramsay.*) It is quite possible that if the iron got oxidised and reduced in contact beds the iron might be retained. In the contact bed we have not found that; in the continuous filters the iron comes through, and you may say in the filtrate there is practically none in solution.

(*Professor Boyce.*) So that really the iron may be a blessing in disguise; if you use the Whittaker bed it may act as one of those very active precipitating agents.

(*Colonel Harding.*) It may.

(*Professor Boyce.*) It has already been used in combination with coke in Germany.

(*Professor Ramsay.*) I do not know whether the Whittaker beds have been tried for domestic sewage.

(*Colonel Harding.*) I do not know. They are of course tried on a larger scale at Accrington than here, but theirs is not pure domestic sewage. I may mention to the Commissioners that they have also tried them at Morley, near Leeds, and they were found to be a failure, but I cannot tell you exactly the details of the experiment, not having seen it, but I should think it because of the quantity of grease coming down with their sewage. I do not know of any case at present where the Whittaker bed has been used for domestic sewage only. Probably Mr. Whittaker will be able to tell us at Accrington.

TWENTY-FIRST DAY.

RIPON.

Wednesday, 25th July, 1900.

PRESENT:

Professor WILLIAM RAMSAY, F.R.S. (in the Chair).

Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Colonel THOMAS WALTER HARDING.
Mr. CHARLES PHILIP COTTON.
Mr. WILLIAM HENRY POWER, F.R.S.

Mr. F. J. WILLIS, *Secretary.*

Mr. WILLIAM EDSON, called; and Examined.

Mr. W. Edson — 25 July 1900.

5309. (*Colonel Harding.*) Mr. Edson, you are the City Surveyor of Ripon?—Yes, sir.

5310. What is the population of Ripon?—About 8,500.

5311. What is roughly the volume of the dry weather flow with which you have to deal here?—350,000 gallons.

5312. How long has this farm been working?—Since 1895.

5313. Before that time did your sewage go untreated into the Ure?—Directly into the Ure—at various points.

5314. And doubtless you are taking this up as the result of various complaints made as to pollution?—That is so.

5315. Your sewage is almost entirely domestic?—Yes, practically. There are two breweries, and three or four varnish works and a tannery.

5316. To what extent do storm dilutions reach you here?—We get the storm water; about half the storm water from 700 acres.

5317. How much is your normal flow increased by storm waters?—I should think it is about double; that is about 700,000.

5318. Even in heavy rain?—In heavy rain it is very much more than that. If you take any heavy storm it will increase at least four or five times that.

5319. Now, on what principle do you work this farm?—Of course, it is laid out in level beds; there are twelve plots.

5320. What is the total area of the farm?—Thirty acres.

5321. But you use for the purpose of sewage treatment 12?—12 acres.

5322. How is that laid out?—That is laid out in 12 level plots and under drained.

5323. (*Major-General Carey.*) To six feet in depth?—To six feet in depth. There are no under drains directly under the beds. That is, the subsoil drains are under the paths.

5324. Intercepting drains?—Yes.

5325. (*Mr. Cotton.*) Are the 12 acres all in osiers?—Yes.

5326. (*Mr. Power.*) Could you use more than the 12 without pumping?—Oh! yes.

5327. You command more than 12 acres if necessary?—Yes, with the exception of about three acres of the remaining 18 acres.

5328. (*Major-General Carey.*) That is 15 you command?—Yes, we can use exactly as we are doing here without pumping.

5329. (*Colonel Harding.*) Then tell me how do you use the 12 acres now used?—The sewage is turned on to each bed for 24 hours. Of course, then it has 12 days—11 days about—rest.

5330. (*Mr. Power.*) You are speaking about the dry weather flow?—I am speaking about the dry weather flow.

5331. (*Colonel Harding.*) You use each acre in turn? Yes.

5332. (*Major-General Carey.*) Is it laid out in acre plots?—Yes, practically.

5333. (*Colonel Harding.*) You use each acre in turn; you turn the whole of your daily flow on to each acre, such daily flow being 350,000 gallons?—That is so.

5334. At the end of the 24 hours you give that bed eleven days' rest, during which time the sewage passes on right through.

5335. Now, how soon does it pass through from the surface?—It varies.

5336. Well about?—The average would be about 2½ days.

5337. How long does it continue to flow from the outlet?—After it has settled through.

5338. After the day on which it was filled?—Well, you see there are four beds down here, and, of course, we use this one to-day, the next one to-morrow, and so on right through.

5339. So that you cannot gauge exactly how long the trickling goes on?—I cannot, without we used this one first and then the far one.

5340. Then after two or three days there is nothing to be seen on the surface?—There is nothing to be seen on the surface.

5341. What are the results that you obtain: have you any analysis taken on account of the city; what analytical results do you obtain?—Well, I think Dr. Wilson will be able to answer that.

5342. You do not yourselves?—We do not ourselves do anything.

5343. But you have reason to think the analyses are satisfactory to the Rivers Board?—Yes.

5344. Have you an analysis of your own sewage?—Not unless Dr. Wilson has it.

Dr. Wilson handed in the following analysis: —

RIPON SEWAGE WORKS.

THE effluents have been at almost every inspection, as they are to-day, bright, clear, free from offensive smell, and producing no bad effects upon the stream. The following are analyses of average samples taken at the same time, and over two hours, from the outfall sewer discharging to the sewage works, and from two of the outlets to the river:—

Sample of	Date.	Total of Solids in suspension and solution.			Solids in suspension only.			Chlorides (as NaCl).	Nitrates (as HNO_3).	Ammonia.		Oxygen absorbed in 4 hrs. at 80° F.	Hardness.		
		Loss on Irrigation.	Ash.	Total.	Loss on Irrigation.	Ash.	Total.			Free.	Alb. (Wanklyn).		Temp.	Per Cent.	Total.
Crude sewage	3/10/99	20·4	52·8	73·2	16·6	11·6	28·2	7·02	nil	1·52	0·68	4·72	21·3	5·3	26·6
Effluent from outlet No. I.	3/10/99	5·2	47·0	52·2	Very small			7·02	2·57	0·27	0·07	0·21	23·0	15·0	38·0
Effluent from outlet No. II.	3/10/99	5·2	42·8	48·0	Very small			6·14	1·80	0·20	trace	0·18	23·5	12·0	35·5

REMARKS.—In solution only:—Ammonia albuminoid - - = 0·25.
Oxygen absorbed in 4 hrs., 80° F. = 2·36.

Rivers Board,
Wakefield.

EDWARD HALLIWELL, F.I.C.,
For H. MACLEAN WILSON, M.D.

Mr. W. Edson. 25 July 1900.

5345. (*Major-General Carey.*) Do you ever do anything to the plots; do you plough them up or rake off the surface?—They have never been disturbed with the exception of these at the outlets here; there are some half pipes laid for carriers down the centre of the beds, and, of course, these channels get full of sludge; this we clear out; we clean out in the spring, when the willows are cut off.

5346. There has been no disturbance of the land itself by ploughing?—There has been no disturbance whatever.

5347. Since 1895?—Since 1895.

5348. And has the effluent always been as clear as we see it now?—Always.

5349. Uniform?—Yes.

5350. It never comes down thick or muddy?—I have never noticed anything different to what you have seen to-day.

5351. (*Colonel Harding.*) Do you find this one day in 12 is sufficient, or do you find the land is becoming sick?—Well, I find a good deal of difference in the land from what it was when we started. For instance, when we turned it on to this point at the start it was running on that plot for a fortnight, and never showed itself on the surface.

5352. (*Mr. Power.*) Day by day for a fortnight?—Day by day for a fortnight.

5353. (*Major-General Carey.*) When you started?—When we started.

5354. (*Colonel Harding.*) The effluent was all right, but it did not stand on the surface. It then gradually got worse?—Yes.

5355. It drank the sewage slower?—It drank the sewage slower.

5356. (*Major-General Carey.*) You used the land at starting by flooding it day after day for a fortnight?—Well, we did not do that as a regular thing, but one or two of the beds. I noticed that the willow growers were anxious that the willows should get a start, and, in order to give them a start we let sufficient sewage run on, and it was running on some of these beds for a fortnight.

5357. (*Colonel Harding.*) Then do you think the time is coming when one day in twelve will be too much to give them?—Yes, I think so.

5358. And you will therefore have to take in additional acreage so as to be able to continue your work?—Yes, I think so.

5359. (*Major-General Carey.*) Especially as you will have an extension and more people coming in?—Yes.

5360. (*Colonel Harding.*) But as you have an extra three acres to fall back upon you have no anxiety as to the future?—We have no anxiety as to the future, as we have 15 acres, not three, available for extensions.

5361. As to the cost of this treatment, can you give us any information as to what is the net cost to the City of the treatment of the sewage?—You mean the working cost.

5362. I want to know what is the net cost to the city after making allowance for any sums you may get by the sale of the osiers?—(*Town Clerk.*) We let the land to a basket-maker at £13 per annum, and he grows his own osiers.

5363. Is this £13 the only return you get?—(*Mr. Edson.*) Practically.

5364. Is that the only expense?—We have got a man here who attends to the farm, and that with pumping sludge and other small expenses costs about £60 or £70 a year.

5365. The expense to the City consists simply of this man you have in charge, and any occasional attention to the drains, and the interest on the original outlay?—That is so.

5366. You are not able to give us the figures representing the cost to the city of Ripon of the treatment of its sewage?—I am not able to give that. The Town Clerk will be able to give you those particulars.

5367. Would the Town Clerk send that to Mr. Willis, the Secretary of the Commission?—(*Town Clerk.*) With pleasure.

5368. (*Major-General Carey.*) It is this land which is let for £13 a year?—Yes.

5369. The other?—The arable land is let for 30s. per acre and the grass land we keep in our own hands for the horses.

5370. That all means you put that into revenue in making a statement of the case?—The rents would be about £50.

5371. (*Colonel Harding.*) Will you tell me, is the information that I am asking you for in the form you filled up for Dr. Wilson twelve months ago?—Yes, I think so.

5372. You need not trouble to send it to us then, because Dr. Wilson has already communicated that to the Commission.

5373. (*Mr. Power.*) When the river is in flood the effluent outfalls are under water?—(*Mr. Edson.*) They are.

5374. Are they under water for any series of days at a time?—Oh, yes.

5375. Then your beds drain much more slowly?—Oh, yes.

5376. It would affect the whole area that, would it not?—I have been down here when the river has been in flood within twelve inches of the banks, and the beds were what you see them now; it had not filtered through.

5377. (*Mr. Cotton.*) How often are the osiers cut?—They are cut every year.

5378. Is there a good market for them?—Yes, I think so.

5379. (*Major-General Carey.*) You do not get any revenue from them beyond the £13 a year?—No.

5380. (*Dr. Russell.*) Have you always got £13?—Yes. The man who has the farm planted the willows; I mean that cost him a considerable sum.

5381. And have there been no complaints since your sewage got rather in excess of your ground of deterioration in the quality of the willows?—Yes. The willow grower tells me that they complain that the willows are not so good as they were. They are not so good in quality as they were at the start.

5382. (*Colonel Harding.*) But if you only derive a benefit of £13 a year from the cultivation of osiers, it seems to me that it does not much matter whether the osiers prosper or do not prosper?—Well, so far as the Corporation are concerned.

5383. (*Major-General Carey.*) Is it a yearly tenancy?—Yes.

5384. (*Mr. Cotton.*) What are the osiers used for?—Baskets, etc.

5385. They are not allowed to grow long for hooping?—Oh, no, sir; he cuts them every year. There is a large quantity of osiers in a shed down there, but he sells most of them.

5386. (*Professor Ramsay.*) What is the depth of the subsoil drainage under the beds?—They are 6ft. below the beds.

5387. How many drains are there?—There are four.

5388. What is the nature of the subsoil below the osier beds?—Below the osier beds it varies; in the top beds there is about 18 inches of fine loam and the subsoil is principally gravel, open gravel; it varies, we get the rough gravel at the bottom, fortunately. The beds down towards the river have about 3ft. of soil from the top before we come to the gravel.

5389. You could then turn up the surface of the soil and remake it?—Oh, yes.

5390. (*Mr. Power.*) At what level do you, on digging down, find the water in the soil within this area?—I believe when they dug this tank here they came to the water when they came to the level of the river.

5391. The particular level of the river at that time, you mean?—Yes.

5392. (*Colonel Harding.*) Have you considered whether by abandoning your crop of osiers and by your occasionally ploughing over your surface, you would not get either better results or a larger volume over the existing area?—Yes, I am rather inclined to think so.

5393. (*Major-General Carey.*) Your rate of dry weather flow is very high?—Well, we get a certain amount of subsoil water. The soil is of a very gravelly nature, and we get a good deal of subsoil water.

Mr. F. BAGSHAW, called in; and Examined.

5394. (*Colonel Harding.*) You are the Borough Surveyor of Harrogate?—Yes.

5395. Your population, of course, varies very much?—Yes.

5396. Can you give us any idea what it is, winter and season?—Well, we estimate the resident population about 21,000 at present, and the season population is an unknown quantity: what would you think?—10,000 additional?

5397. (*Mr. Power.*) At the height of the season, additional 10,000?—Yes.

5398. (*Colonel Harding.*) Within what limits does the volume of your sewage vary in its normal flow?—The dry weather flow is about 700,000 gallons.

5399. When was that taken; in the winter?—That was taken in November after very dry weather indeed for several weeks.

5400. But I take it the volume will vary very much according to the population?—From 700,000 to 1,000,000.

5401. Does the surface water pass into your sewers?—We have taken out a very large proportion within the last few years. We are laying down a separate system for storm water. There is a certain quantity gets into our sewers, but that will be obviated when we have laid down our surface water drains.

5402. What is the total volume that you have noticed here—the highest?—1,100,000; nearly 1,200,000 gallons; that is what we have got.

5403. That is not much beyond your normal flow?—That is our last gauging.

5404. But you told us your normal flow varied from 760,000 to 1,000,000 gallons?—Yes.

5405. Now you tell us that the highest total volume you have noticed is 1,100,000 to 1,200,000 gallons?—That is what we have gauged, we have not gauged it lately.

5406. Are we to understand that the bulk of the street overflow goes elsewhere?—Yes, into the natural watercourses.

5407. What is the acreage of this farm?—310 acres.

5408. How long have you been treating your sewage at all?—Considerably over 20 years.

5409. Then you do not treat your sewage before putting it on to the land at all. You do not add any chemicals?—No, nothing at all, simply run on crude sewage.

5410. You have a settling ground, to settle the crude sewage?—Yes.

5411. And a very rough screen?—To screen off the detritus.

5412. The principle you work on is to flow it over the land through grips?—Yes, cut on the surface.

5413. And you are constantly varying the position of these grips?—Yes, every day almost.

5414. And what is the crop that you raise mostly?—Well, rye grass I think is the principal crop we have here.

5415. Then it is mostly pasture?—Yes, of course we have a good deal of store cattle here.

5416. (*Mr. Power.*) You have a large extent of stock?—They are bought, fattened up, and sold in the market.

5417. And milch cows too?—No, no milch cows.

5418. (*Colonel Harding.*) All effluent is passed into the brook?—Yes.

5418*. Have you had any complaints of the brook by the people lower down?—One or two that I have heard of.

5419. Are you proposing to improve the treatment of your sewage in any way beyond what you have shown us?—Excepting that we are proposing to move it away altogether. *Mr. Frank Bagshaw.* 25 July 1906.

5420. To another site?—To another site.

5421. Years hence?—As soon as we get the extension of the borough.

5422. But you will have to treat it here for some years to come?—Probably; until the new scheme is ready.

5423. What is the nature of your soil here?—Principally clay on this ground.

5424. How deep have you to dig down to reach the clay?—It varies from six inches. There is very little soil; take it as a whole it is principally clay. The farm manager stated that at some places there were two feet of soil, but these are exceptional instances. I do not know of any place where it is two feet deep—the soil; it may be occasionally.

5425. You find the sewage from these grips flows very near the top or over the top of the land?—That is so, yes.

5426. (*Major-General Carey.*) Is it all clay?—Nearly all clay on rock.

5427. On both sides of this hill?—Yes; we built the farmhouse out of stone, which we got within our farm. (*Dr. Wilson.*) Some of the sewage goes on to the land above and on to the lower part as well, a second time. (*Mr. Bagshaw.*) Yes.

5428. (*Colonel Harding.*) Then you do not get any analyses made by your local analyst?—No. Well, we have recently had tests for two small bacteria beds we have put down, but not for the farm itself.

5429. The only knowledge of the results you get is by the criticism of the Rivers Board?—That is so.

5430. (*Major-General Carey.*) What is briefly the result of your experience with the bacteria bed?—Well. I know it has been very satisfactory, but it is only a very small bed indeed.

5431. It is a single contact bed?—Yes.

5432. You have no double contact beds?—No.

5433. And obtain very fair results?—Yes, with the experiments we made.

5434. How long has it been working?—Twelve months.

5435. Have you any idea of extending the beds?—Not at present.

5436. Have you ample area of land?—Yes, if the sewage be properly treated, but we are going in for a new farm at a greater distance from the town when the borough is extended.

5437. (*Mr. Power.*) And a larger farm?—Yes.

5438. (*Colonel Harding.*) We are obliged to you, Mr Alderman Milner, for showing us round. It seems to me that the results you obtain depend very much upon the way in which your manager works his farm. If he takes great care in cutting his grips and seeing that the sewage really passes through an adequate amount of land so as to get properly treated, you will get very fair results, but he must be careful that it does not run right down and not get properly treated. It ought to be very carefully watched by the Rivers Board?—We have two men to look after it; two men that we do not charge to the farm account.

5439. (*Mr. Power.*) Do you let the farm to anybody?—No.

Dr. Wilson handed in the subjoined analysis as a typical analysis.

HARROGATE SEWAGE WORKS.

Mr. F. Bagshaw. 25 July 1900.

THE Effluents from Harrogate Sewage Works vary enormously in purity, being sometimes very satisfactory, and sometimes nearly as bad as crude sewage. The results depending entirely on the attention to the distribution of the sewage upon the land. The following are analyses of the crude sewage and of effluents taken at various times. The effluents frequently have a strong smell of sulphuretted hydrogen, and in such cases the back-water, which contains iron, becomes distinctly darkened in colour.

Sample of	Date.	Total of Solids in suspension and solution.			Solids in suspension only.			Chlorides (as NaCl).	Nitrates (as HNO_3).	Ammonia.		Oxygen absorbed in 4 hours at 80°F.
		Loss on Irrigation.	Ash.	Total.	Loss on Irrigation.	Ash.	Total.			Free.	Alb. (Wanklyn).	
Crude sewage, average over 2½ hours.	5/1/99	54·0	76·4	130·4	38·4	44·0	82·4	8·18	—	4·43	1·30	7·83
Effluent to Cow Dyke Beck, average over 2½ hours.	5/1/99	—	—	—	—	—	—	7·31	—	—	—	6·43
Effluent to Oak Beck, average over 2½ hours.	5/1/99	11·5	39 1	50·6	—	—	—	8·50	2·56	1·53	0·107	1·00
Effluent to Oak Beck, average over 2½ hours.	5/1/99	—	—	—	—	—	—	7·60	—	—	—	1·20
Effluent, Skipton Road side to Oak Beck,	6/7/99	—	—	—	—	—	—	12·90	—	—	—	1·44
Effluent to Cow Dyke Beck.	6/7/99	—	—	—	—	—	—	14·64	—	—	—	3·30
Effluent to Cow Dyke Beck.	6/7/99	—	—	—	—	—	—	12·30	—	—	—	1·60
Effluent to Skipton Road side to Oak Beck.	18/8/99	—	—	—	—	—	—	15·21	—	—	—	1·28
Effluent to Cow Dyke Beck.	18/8/99	—	—	—	—	—	—	15·79	—	—	—	4·78
Effluent to Cow Dyke Beck	28/9/99	—	—	—	—	9	—	14 04	—	—	—	2·37
Effluent to Oak Beck	28/9/99	—	—	—	—	—	—	14·62	—	—	—	1·08
Effluent to Skipton Road side drain to Oak Beck.	27/11/99	—	—	—	—	—	—	9·94	0·99	—	—	1·66
Effluent to Skipton Road side to Cow Dyke Beck.	27/11.99	—	—	—	—	—	—	12·28	3 06	—	—	0·66
Effluent, Target Field to Cow Dyke Beck.	27/11/99	—	—	—	—	—	—	12 28	3·60	—	—	1·00

EDWARD HALLIWELL, F.I.C.,
For H. MACLEAN WILSON, M.D

TWENTY-SECOND DAY.

MANCHESTER TOWN HALL.

Thursday, 26th July, 1900.

PRESENT:

Colonel THOMAS WALTER HARDING (in the Chair).

Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Dr. JAMES BURN RUSSELL.
Mr. THOMAS WILLIAM KILLICK.
Mr. CHARLES PHILIP COTTON.
Mr. WILLIAM HENRY POWER., F.R.S.

Mr. F. J. WILLIS, *Secretary.*

Mr. GILBERT J. FOWLER, M.Sc., F.I.C., Superintendent and Chemist of the Manchester Corporation Sewage Works, called; and Examined.

Mr. G. J. Fowler, M.Sc., F.I.C. 26 July 1900.

(*Chairman.*) I should like, Sir Bosdin Leech, to express to you, on behalf of the Royal Commission, our appreciation of the readiness and courtesy with which the Corporation of Manchester have placed at our disposal a large volume of information, not only in connection with the question of sewage disposal in Manchester, but in regard to its past and its future. The information placed in our hands is voluminous, and is in a form that we cannot conveniently incorporate into our proceedings, and our object this afternoon is not to any extent critical; we do not propose to cross-examine upon the matters that are brought before us—the object of our questions this afternoon is really to get upon our Minutes, in a somewhat convenient form, the mass of information which is before us in these various and successive reports. I am sorry, therefore, that the examination this afternoon will necessarily be rather tedious, I am afraid, to you, Sir Bosdin, and the members of our Commission, and possibly to the witness himself whom we propose to examine. I should like to thank Mr. Fowler himself for the draft which he has sent each of us and for the information which he has placed before us, no doubt at considerable trouble to himself. We appreciate very much the trouble you have taken, Mr. Fowler, and the information you have placed before us is very interesting and very useful. With the permission of my colleagues, therefore, I will proceed.

5440. Mr. Gilbert J. Fowler, you are, I believe, the Superintendent and Chemist at the Davyhulme Sewage Works of the Corporation of Manchester?—I am.

5441. How long have you been connected with these works?—Since May, 1896.

5442. Although you have at those works been making a number of very interesting experiments in the bacterial treatment of sewage, you have in those experiments been dealing with a very small volume, and I take it that the bulk of your sewage is treated by chemical precipitation?—That is so.

5443. You made, in 1897, certain experiments in sedimentation without chemicals?—Yes.

5444. Will you tell us quite briefly what results you found from those experiments?—Quite briefly, we found that the effluent was of a rather more turbid character than from chemical treatment, and was, moreover, more offensive on incubation. That was one of the results which we were most struck with. We found, further, that about 50 per cent. of the total impurity was removed by sedimentation alone, and consequently we

drew the conclusion that the addition of chemicals only served to remove perhaps an additional 15 per cent.

5445. Then there was nothing encouraging, and you proceeded with chemical precipitation?—That was so, s.r. yes.

5446. What are the precipitants that you use?—For the most part we have used lime and copperas.

5447. In varying quantities, according to the condition of the sewage?—In varying quantities, according to the condition of the sewage; very much lime if we happen to have iron salts coming down, and, on the other hand, the lime will be knocked off entirely if we should happen to have a certain amount of bleaching powder in the sewage. These are two extreme cases. And, of course, there are times when a good deal of acid comes down from various chemical processes—for instance, naphtha washing, when the sewage will contain a certain amount of sulphuric acid, and, under other conditions, what the workmen call blind acid, which is really carbonic acid. It does not affect the litmus paper, but, of course, it consumes a large quantity of lime, and we have men constantly watching the sewage and testing with phenol-phthalein. They have also litmus paper to test whether there is free acid present, and they regulate the application of chemicals accordingly.

5448. What is the normal flow of your sewage?—At present the normal dry weather flow will be about 27,000,000 gallons, but in regard to that I perhaps may be allowed to say that it hardly represents the actual flow of sewage, because it represents a consumption per head of something like 60 gallons a day, which is far in excess of the water supply, and, consequently, we calculate that there is a considerable amount of subsoil water which finds its way into the sewers. Of course, a great many of the sewers are constructed very loosely; some of the old sewers most especially, and it has been calculated by Mr. Baldwin Latham from rainfall observations and from other observations, and also by comparing the water supply of the city that this subsoil water will amount to something like 6,000,000 or 8,000,000 gallons per day, so that the actual sewage flow might very well be taken at about 20,000,000 gallons.

5449. The population of Manchester, I think, is 530,000?—Yes. That will give you, you see, something like 40 gallons per head.

5450. By this system of chemical precipitation you obtain a large volume of resultant sludge; what is the volume which you obtain?—We obtain on an average about 21 tons per million gallons.

5451. Will you tell us what is the total production of sludge at the works?—For 1898 it was 200,000 tons of 90 per cent. sludge.

5452. And how do you dispose of this sludge?—It is pushed from the bottom of the tank by men with wooden squeegees, as they are called. They push it through valves at the bottom of the tank into a channel along which it flows to two Shone's automatic ejectors, through which it is forced by means of air pressure of from 35 lbs. to 40 lbs. to the square inch through a main—a cast iron main—to two storage tanks close to the Ship Canal, from which it can flow by gravity into the sludge steamer, which takes it beyond the Mersey bar and deposits it there. Each tank will hold 1,000 tons, and the steamer itself holds 1,000 tons, so that the steamer takes one tank at each trip, and on an average the steamer will make something like four trips per week. That is 4,000 tons of wet sludge are removed per week.

5453. I find by one of the statements that you have been good enough to put before us that the cost to the City of Manchester of carrying out that system of treatment is £5,387 per month, so far as the last twelve months is concerned?—Per year is it not, sir?

5454. The column says total per month. Oh, I see this says that the cost is £5,387 per year?—That is so.

5455. Then do you happen to know what is the total cost to the City of Manchester of the treatment of sewage, inclusive of the interest on the capital outlay?—I have sent for that information.

5456. Perhaps you will be able to put it in later?—I may be able to get it.

5457. Now, what is the result in purification of the treatment of Manchester sewage by chemical precipitation?—Practically reckoning on the crude sewage we get on an average about 50 per cent. purification.

5458. Then your tank effluent, having thrown down the greater part of the suspended solids, contains impurities in solution?—That is so. *Mr. G. J. Fowler, M.Sc., F.I.C.* 26 July 1900.

5459. And requires obviously further treatment?—Certainly.

5460. What is the area available at Davyhulme?—The total area available for filter-beds will amount to about 80 acres without any possible extension; that is to say, taking the present ring fence.

5461. And that is obviously too small for any system of land treatment?—Of land treatment certainly.

5462. The attention of the City of Manchester has therefore been directed to bacterial processes?—That is so.

5463. Now, certain experiments were made at the suggestion of Sir Henry Roscoe so far back as 1895 in the direction of small bacterial filters?—That is so.

5464. And those filters have treated the effluent from chemical precipitation?—Yes, with the exception of occasions when during storms, for instance, the treatment was suspended for a short time, but generally speaking, it was the effluent from chemical precipitation.

5465. The experiment was quite on a small scale; there were, I believe, two small beds of about 25 square yards area each?—Yes.

5466. The results were generally encouraging as to the quality of the filtrates?—Very encouraging, yes.

5467. I understand that you find after working those small experimental beds since 1895 that dealing with such effluent as you put upon them containing only, I am told, four grains per gallon suspended solids, you have been able to maintain capacity?—To a very large extent, yes.

5468. The capacity fell rapidly at first, but you have been able to maintain it since?—Yes, to be absolutely correct the last measurements have been slightly less than some previous, but we are still dealing with a large quantity. The last capacity of the cinder bed was about 1,000 gallons.

5469. What was the original water capacity of those two small beds?—1,750 gallons each.

5470. And what was it when last measured?—I will give it you exactly. The cinder filter was 1,008 gallons, and the coke was 972 gallons. That was on the 28th June last.

5471. Then are we to take it that those beds have never been since 1895 reconstructed, having been merely forked over or raked over?—That is all, and the matter on the top has been gathered into heaps, that is all, but nothing has been added to or taken from them.

5472. Now, as the result of these experiments, it was suggested in 1898, was it not, that the system of sewage treatment that might be suitable for this city was a system of such filtration following upon chemical precipitation?—That was so.

5473. But about that time, in 1898, the Council of the city decided to consult certain specialists?—Yes.

5474. Those specialists were: Mr. Percy F. Frankland, Mr. W. H. Perkin, jun., and Mr. Baldwin Latham?—Those were the names.

5475. They reported to the city on October 30th, 1899, in a report which has been published and a copy of which has been submitted to us. They examined various schemes which had been proposed, and they made certain experiments and they drew certain conclusions. That was so, was it not?—Yes.

5476. Now I believe they have made experiments in double contact filtration of crude, and partially settled sewage at Davyhulme, and they came to the conclusion that it was not practical to deal with crude sewage or partially settled sewage upon contact beds unless the bulk of the larger part of the suspended solids had been first removed?—Certainly.

5477. The result as to the quality of the filtrates which they obtained was good, but the capacity of the filters was too easily reduced?—That was their opinion.

5478. And in view of the cost of chemical precipitation and the vast amount of sludge produced, they did not propose to adopt chemical precipation as a first process antecedent to filtration?—No.

5479. They thought that the septic tank was more

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promising, as bringing about an equalisation of the sewage and as digesting probably a large part of the suspended solids, and so greatly reducing the sludge production?—Yes.

5480. Well, you can tell us of your own knowledge, Mr. Fowler, about the experiments which have been made at Manchester in connection with closed and open septic tanks in 1898 and 1899?—To begin with the closed septic.

5481. But can you tell us that from your own knowledge?—Yes, certainly.

5482. I take it, in regard to the earlier experiments I have been speaking of, they were before your time; they were conducted by Sir Henry Roscoe in 1895?—That was about three months previous to my appointment, which was made in May, 1896. I think the filters began to work in January, so that I can speak to these filters from May, 1896.

5483. But in regard to the septic tanks, the whole of the experiments have been within your own time and within your own knowledge?—That is so.

5484. You tried experiments with closed septic tanks?—Yes.

5485. I think you had a plant and a set of filters constructed upon the lines suggested by Mr. Cameron, of Exeter?—Yes.

5486. What was the volume treated in that plant?—It has varied somewhat, but the capacity of the filters may be taken at about 12,000 gallons. Taking it altogether, we may say we have treated 24,000 gallons per day through that septic tank.

5487. Then was that flow at such speed that the tank would be filled in 24 hours?—It would be more than filled in 24 hours.

5488. Would it be filled in 12 hours?—Not quite. The capacity of the tank is 20,000, and it was constructed, I believe, to be equal to the capacity of the filters. It is practically equal to the holding capacity of the filters, inasmuch as the filters are filled twice a day; the flow of sewage through that septic tank has been really at twice its capacity per day; the tank capacity is half the daily flow practically.

5489. Then that is a 12 hours speed?—Twelve hours speed, yes.

5490. Now, what was the purification obtained by the single contact filtration following upon the closed septic tank treatment?—It was very satisfactory. I can give you figures which show that for nine months at any rate out of 18 we have practically never had a putrefactive sample. We have not always reduced the actual oxygen absorption figure below the limits set us by the Mersey and Irwell Joint Committee, but there has always been a large amount of nitrates present which has been sufficient to oxidise any residual impurity which might be left.

5491. But, as a fact, do you come down in the analytical results to the standard of the Mersey and Irwell Committee?—Not in all cases; in many cases we did, but not in all cases.

5492. Now you have tried extensive experiments with open septic tanks?—Yes.

5493. Tell us, did you find any material difference in the results of the closed septic tank as compared with the open septic tanks; how did the effluents differ in each case, if at all?—Chemically they were as near as possible identical.

5494. And in appearance?—And in appearance also.

5495. Now those experiments in open septic tanks, I think, consisted mainly in an experiment with one of your old chemical precipitation tanks?—Yes.

5496. What was the capacity of that tank?—1,118,000 gallons.

5497. Its general form, I think, is a long rectangle, is it not?—Yes.

5498. About three times the breadth?—300 feet by 100 feet.

5499. That is three times?—And sloping somewhat towards the inlet, and with an average depth of six feet.

5500. You will appreciate how important it is to ascertain the result of different speeds of flow through septic tanks?—Certainly.

5501. Then what was the speed of flow which you adopted in this experiment?—Originally the speed was 1,700,000 gallons per day, and subsequently it increased to 2,500,000 gallons.

5502. Then you began at first at what we speak of as a 24 hours' speed, and after you increased to a 12 hours' speed?—Roughly speaking, that was so.

5503. How long did you work on a 24 hours' speed?—Practically six months, I think I may say. It was started on February 16th, 1899, at the rate of 1,700,000 gallons, and on October 18th, 1899, the flow was increased to 2,500,000 gallons.

5504. Now, were you able, by comparing the first six months with the later period, to judge of any differences due to the varying speed of flow?—I have no hesitation in saying that the amount of suspended matter passing from the tank and the amount of silting was considerably greater during the latter period. We made measurements of the silting during the later periods, and it was certainly increased more rapidly than at first.

5505. I am afraid I do not quite appreciate your answer. Do you mean to say that working at the slower speed you got more solids?—No; on the contrary, at the greater speed we got a greater accumulation of solids in the same time; the effluent rapidly became worse as regards suspended matter.

5506. While you were working at the quicker rate?—While we were working at the quicker rate.

5507. And you found an improvement in that respect by working slower?—Certainly.

5508. But might not that increase in the solids in suspension in the later period be due to the gradual accumulation of sludge in the tank itself, which would so reduce the capacity of the tank?—I think that is quite possible.

5509. So that, in fact, you are unable to speak with any certainty of definite results comparing the slower with the faster speed?—The results are not as accurate as I should like.

5510. Then your experiment with open septic tanks is really limited to the no doubt considerable experiment of that one tank?—With the exception of a second tank, which I have recently put into working condition with chemically treated sewage.

5511. Then recently you have started a second tank, the difference between that and the other being simply that in that case you have used sewage in which lime had been mixed?—Lime and copperas, yes.

5512. Have you found any practical advantage in adding lime to the sewage for septic tank purposes?—Not as far as I can see, no.

5513. A needless expense, in your opinion?—I think so.

5514. Now, in this first septic tank you accumulate of course a certain amount of sludge matter, due to the flow itself, but I understand that there was tipped into the tank a number of loads of garbage?—Yes.

5515. To what extent?—279 wheelbarrows full.

5516. The idea being to test whether those would be rapidly reduced?—Yes.

5517. I suppose you are not impressed with the utility of a septic tank taking this extra work beyond that which it would naturally have to deal with in the flow?—No. I think my feeling would be to settle it as much as possible.

5518. Then how long did you find that the tank took before evident septic conditions appeared?—Speaking from memory, I think it would be some three months before there was any appearance—any prolonged appearance of scum. It depends somewhat on the weather, of course. In the course of a few days it will begin to give off gas, but it will be by no means thoroughly septic before some months.

5519. In the later period you no doubt found that the flow was black in colour?—Yes.

5520. In the earlier period that did not appear?—No.

5521. Then if it takes several months to develop septic conditions, it would appear to be a disadvantage to empty septic tanks when accumulations arise, because in that case you have to begin *de novo* and lose many weeks before the full septic condition is developed?—That is so.

5522. How soon did you find that scum to any extent appeared on the septic tank?—Speaking again from memory, I think—well, the septic tank was started in

February, the scum appeared in May—I think it was after the Local Government Board Inquiry, as far as I can recollect.

5523. Four or five months after the tank had been started?—Yes.

5524. To what extent did that scum develop?—Eventually it formed a fairly solid cake over about one-third of the tank, and the rest of the tank was covered by a thinner scum on very still days, but this was very readily blown aside by any wind that there might be.

5525. Did you notice much variation in the thickness or other characteristics of the scum after it had appeared?—No, if there was a heavy storm of rain or wind occasionally, it was broken, and it was driven into one corner of the tank, but as far as our observation went it remained very much in the same condition. Every now and then, of course the surface was broken by great ebullitions of gas.

5526. Did you notice whether in winter the scum was thinner or thicker as compared with the same scum in the summer months?—That we have not definite evidence upon.

5527. Are you able to tell me what is the average of solids in suspension in Manchester sewage? I am aware that it varies very considerably indeed, but over a long period what is the average of suspended solids in Manchester sewage?—As far as our observations go it will come to about 20 grains per gallon dry solids, and possibly we might get it out in another way if I take the amount of sludge produced which is at the rate of 20 tons per million gallons. Now, one ton per million gallons, that is of 90 per cent. sludge, you see, so that means two tons of dry matter.

5528. Per million gallons?—Per million gallons, so that that will be on the average 30 grains, you see; that is taking the whole; that is with the chemicals added; that is how it works out.

5529. But my query is irrespective of chemicals; in the sewage itself before chemicals are added?—That I can only give you from our own observations, and in dry weather the average works out at about 20. but it may go up to very large figures, and I am afraid we have not got observations which will enable me to say exactly what it would be over a long period of dry or wet weather, taking it day by day for any long period.

5530. Then you really are unable to tell us what, taking the dry and wet periods together, would be a fair average to reckon for the suspended solids in the Manchester sewage?—Unable otherwise than through the amount of sludge produced.

5531. Have you taken careful note of the suspended solids in the effluent from the septic tanks?—Yes, we have a number of observations of them.

5532. Then what do you find over the period we are speaking of in the life of these septic tanks; what do you find to be the average in the effluents of the septic tanks and flowing from them?—It was working altogether 14 months, and I should say, from the observations we made (I have an average we worked out during that time); it worked out at something like seven grains, but in the earlier period for the first four months very very little, and then it averaged up to 20 grains.

5533. But the 20 grains would scarcely be an average condition?—Oh, no.

5534. That would be a sort of maximum condition?—That was the maximum, yes.

5535. Do you think the seven grains you spoke of could be taken as an average of the later period?—No, at the last it was over seven grains—the last few months

5536. What would it be?—I should say something like 15.

5537. Then during the whole of the period to which you have referred from February, 1899, until April, 1900, you removed nothing whatever from the tanks?—No.

5538. But towards the end of the period judging from the increasing quantity of suspended solids coming out, you came to the conclusion that it was necessary to either empty the second septic or remove some of the accumulations?—Yes.

5539. As a fact you decided to empty it?—Yes.

5540. How did you do that?—We fixed a steam boiler and pulsometer pump at the far end, and pumped down until we found that we were pumping sludge. There was a fairly well defined line between the water and the sludge. We ascertained it by the dipping tube first of all, and we pumped down to just about that level, and then afterwards we sludged the tank in the usual way through the channels and into the sludge steamer.

5541. Then you estimated the amount of sludge in first of all, and we pumped down to just about that level, had taken away the top waters?—Yes.

5542. But that itself would contain quite a material amount of suspended solids?—No doubt.

5543. Did you form then an estimate of the volume of sludge that had been digested by your septic tank in the period referred to?—Yes.

5544. What was the conclusion you came to?—Taking one thing with another we came to the conclusion that from a half to two-thirds had disappeared.

5545. It is, of course, of deep interest to us to know whether septic tanks consume, and if so, how much they consume of the suspended solids put in. We should be therefore very much interested if you would tell us how you reached the conclusion that you have just mentioned?—Briefly, I arrived at it in this way. We had been throughout 14 months putting sewage through that at the rate of 2,000,000 gallons per day on the average, that is to say, of course, it was rather less at the early period, rather more later on, so I take it at 2,000,000 gallons per day, and that gave us a residue of 4,000 tons. Now, taking 30,000,000 as our daily flow, we should get on that flow a total residue of 60,000 tons in 14 months. Our year's production is 200,000 tons, therefore according to that, if you take that bare figure, rather more than two-thirds had disappeared, but inasmuch as there undoubtedly was a considerable amount of solid matter going away I concluded that it must really be less, but it seemed to me to be probable that it would be something more than half which had disappeared. But as a matter of fact, to find out what exactly has been digested and absolutely destroyed is a rather more difficult question, and recent observations with regard to the closed septic tank might perhaps throw some light on that. One has to consider of course that, as far as destruction is concerned, the inorganic residue must be dealt with somewhere either on the surface of your beds or as sludge, so that you may take that as remaining constant all through. Now, on the average the suspended matter in Manchester sewage will contain 40 per cent. at least of mineral matter. Now, that mineral matter will always have to be dealt with, so you have left 60 per cent. of organic matter. Now, we have found from a number of experiments that the sludge left in the septic tank—and in our experiments with the open and closed septic tank we have always identical results—the sludge left, instead of containing 40 per cent. of mineral matter will contain 60 per cent., so that there has been a reduction of the organic matter, and on working that out proportionally it works out that about half the organic matter in the sludge has disappeared, and that appears to me to be on careful consideration as much as the septic tank alone will absolutely digest; that is to say, working at the rates at which we have been working. Of course, there is this to be said, that any organic matter that passes away with the suspended matter in the effluent, and is taken on to the surface of the beds will be very readily oxidised, or very largely so. I am bound to say that is one of the questions on which I think we require a little further time.

5546. But there is no sort of doubt in your mind that inasmuch as your analysis of the sludge deposit in the septic tank shows that somewhat more than half of it is organic matter, there must be of necessity a steady accumulation in a septic tank?—Of necessity.

5547. And that something will at the same time have to be removed?—I think that is unquestionable.

5548. And you tell us that you have determined upon an estimate of a half or two-thirds—probably something between those two figures had been consumed; that the basis of your calculation is scarcely such as to lead you to form a very strong opinion as to that proportion being one that can be relied upon?—I think that would be my conclusion, to discover what is absolutely destroyed, absolutely dissolved or given off as gas is not quite a simple problem.

5549. What you propose to do in future is to carefully ascertain what is the average of the suspended solids in your sewage, also what is the average of the suspended solids in your effluent, and then taking the difference between the two as representing what is left in the tank by the average gallon, you will multiply by the volume

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which has been dealt with in the period, and you will in that way with fair accuracy gauge what has been consumed?—That is our opinion.

5550. You are not now in a position to say definitely what is the amount consumed, but you think it is about half?—That is my estimate. I have endeavoured to give you the facts.

5551. Now, you probably took some care to ascertain the temperature not only of the sewage but of the effluents from the septic tanks?—Yes.

5552. What was the mean difference in temperature between that of the sewage and that of the effluent?—Well, so far as my observations went I always found that there was a slightly lower temperature in the effluent of the septic tank than in the sewage that went in.

5553. What difference in degrees?—About one degree centigrade, perhaps.

5554. Then that would probably relieve you from anxiety as to the working of the septic tank in all weathers?—I have not any.

5555. It is always ten degrees hotter than the atmosphere?—Yes.

5556. As a general rule what was the minimum temperature of your septic tank?—6 to 9 degrees, I will show that.

5557. If you can without much trouble?—They are here. I think the lowest temperature that I have here is 6·5 Centigrade; that would be about 40 deg. Fahrenheit; something thereabout.

5558. You would not, I suppose, find that you had ice on the top of the septic tanks?—No ice on the top of the septic tanks, but we have had snow on the top of the scum.

5559. Did you find the scum itself useful in preserving the heat of the septic tank?—That is so, yes.

5560. The snow gathered on the surface of the scum?—The snow gathered on the surface of the scum.

5561. And the scum itself is a bad conductor of heat?—Yes.

5562. So that in winter this is quite useful to the extent that it conserves the heat of the sewage in the tank?—That is what we have found.

5563. What do you think would be the effect of the varying flow due to dilution of the sewage in connection with septic tank treatment. What I mean is that if you arrange your septic tank to take a certain speed of normal flow, when you get dilution by rain you would get a quicker flow through the tank; have you been able at all to gauge what the effect of such dilution would be?—We have worked our tank—the open septic tank—just according to the flow of the sewage. If there was a storm there would be a greater head in the bypass, and consequently it would receive more at one period, and we have not found that it seriously affected the results.

5564. You never reach such flow as would for instance wash out the septic tanks?—Oh, no.

5565. And you do not anticipate that with, say, three dilutions, there would be any danger of injuring the septic conditions of the tank?—No, not with three dilutions.

5566. (*Professor Ramsay.*) In filling the septic tank do you draw through the middle of the pipe through which the sewage flows?—There is a bypass which is 18 inches from the invert of the sewer.

5567. Do you think that that gives a fair sample of the sewage?—As far as our experiments have gone; I have made some determinations; I have used the small settling tank at the inlet of the large tank and bucketted out the sludge from that volume of sewage and found that there was an amount comparable to what we should have got from ordinary sewage, and so I calculate that practically there was very little difference. It is a point which is rather difficult to determine, because it has always been difficult to get a sample even of raw sewage which shall be right, taking the whole thing from the bottom of the sewer, but as far as we could tell we got a pretty fair sample.

5568. The sewage contains a quantity of tar, does it not?—Well, hardly of tar, but of tar products.

5569. Would they not float?—In many cases we get oils and such like, and certain light matters would.

5570. Do they affect the septic tank at all, or do they enter it?—They enter it and we can smell the tarry odour. My feeling about it is rather that they have acted to some extent as deodorants, and consequently we have had less trouble on the score of smell than we might otherwise have had.

5571. (*Chairman.*) I omitted to ask you if you had found any nuisance arise from smell from this septic tank dealing with these 2,000,000 gallons?—Only I think in certain conditions of the atmosphere. If you have a very quiet muggy night, so that the gases cannot get away and are held over the surface of the tank, then there is rather an unpleasant odour about it, but on a day like to-day—well, the Commissioners could tell for themselves that there is practically no odour.

5572. Have you examined and analysed the gases so as to form an opinion as to what those gases mostly are?—Yes; we found that they consisted of nearly 90 per cent. marsh gas.

5573. Which is inodorous?—Yes.

5574. General Carey wishes me to ask you as to the depth of sludge in your septic tanks. You have no doubt tested that at various periods and taken a record of the depths of sludge?—Yes.

5575. Have you at different periods in the history of your septic tank?—Well, since starting this new one we have taken it practically every week.

5576. And you have a record of those?—And we have a record of those.

5577. Now we may pass away, I think, from the septic tanks. What the Rivers Committee have had in their minds has been the septic tank as a first process and contact filtration as a second?—Yes.

5578. Speaking generally, do you think that a good enough result can be brought about by single contact filtration of septic effluent?—Yes, as regards the filtrate; as a rule that is so, provided that you get a thoroughly septicised sewage. With merely settled sewage I do not think that you can get a good enough result with one contact.

5579. My inquiry relates entirely to the treatment of septic effluent?—Well, with one contact you can get——

5580. You wish the Commissioners to understand that with one contact you can rely upon obtaining an effluent which may be within the Mersey and Irwell standard?—Not always within their numerical standard; no, that I cannot always attain.

5581. You suggest that though it may be somewhat above the Mersey and Irwell standard yet it will not be putrefactive?—No, because under any good conditions it should have enough nitrate to prevent that.

5582. You have, of course, made frequent tests by incubation?—Every sample practically is tested in that way.

5583. Now by double contact filtration you have obtained, I believe, very good results, have you not?—Oh, yes.

5584. Steadily below the Mersey and Irwell standard?—Without any exception at all.

5585. And of course it is not putrefactive?—Oh, no.

5586. Well, now, in your experiments in contact filtration you have used, I believe, the four small beds, A, B, C, D, with which you have been previously experimenting with crude sewage and settled sewage?—Yes.

5587. Did you reconstruct them for the purpose of the experiments with septic effluent?—No; for that purpose one bed—bed A—was reconstructed in order to get finer material, but not simply in order to experiment with septic effluent, but bed C began with settled sewage for a short time, and then took septic effluent.

5588. The results obtained would be more relative if we took them from the time that you reconstructed the beds?—Yes.

5589. Now A and C have been primary beds?—Always.

5590. D has been a secondary bed used in connection with these primary beds?—Yes.

5591. And B is a bed which you have used for independent experiments in single contact?—Yes.

5592. What was the area of these beds; was the area the same for them all?—Yes, it worked out equal to a rectangular bed of one 76·3 of an acre. It would take 76·3 of such beds as those to make an acre.

5593. What was the volume—the water capacity of these beds originally?—5,000 gallons each.

5594. What was the water capacity before any of the filtering material was put in?—10,000 gallons.

5595. Was the 5,000 common to all four?—Yes

5596. And was that he original water capacity at the time when this series of experiments began?—No, it was rather less at that time.

5597. How did the material in those beds differ at the time when you used them for dealing with septic effluent?—The material of A was the same material as had been used previously for dealing with settled and raw sewage, but it was broken down more finely, and I can tell you in one moment—the material was broken down so as to pass a three-quarter inch mesh, and be rejected by one-eighty, whereas previously we had to put in as big as two inches.

5598. Well, in D and B the material did not differ very much, did it?—No, the only difference that was made in D and B was simply to put coarse material over the drain pipes. The main body of the bed was not altered, but it was found that unless the drain pipes were protected by coarse material the channels tended to get choked with the detritus, the waste from the bed. We have had no trouble since, we have just protected them by big lumps of cinders so as to improve the drains; it was simply a question of drainage.

5599. And I think you have found that the work of the secondary beds was much lighter work than that of the primary beds?—Unquestionably.

5600. That the bacterial action was more rapid upon dissolved than upon suspended impurities?—There is no doubt of that, I think.

5601. And I think you reached this result, did you not, that you could use one secondary bed as following two primary beds?—I think we have proved that almost to demonstration.

5602. Then as the result of your experiments you probably have reached a conclusion how much burden could be thrown upon primary and secondary beds; will you give us your opinion upon that?—I have come to the conclusion that you can work your primary beds at an average speed of three-quarters of a million gallons per acre per day if you give them Sunday's rest and one week's rest in a month.

5603. When you say three-quarters of a million gallons per acre per day, do you mean the coarse bed only or are you including double filtration?—I am speaking of the first bed only—that is to say, I calculate my contents of the bed at one-quarter of a million; at three fillings, that amounts to three-quarters of a million.

5604. For that bed only?—For that bed only.

5605. When one speaks of three-quarters of a million for one secondary bed following a primary bed, the volume per acre will be half that?—Half that. If you had one bed for one secondary, certainly yes.

5606. If you have one secondary bed following two primary beds what would be the volume per acre which you would find practical to be dealt with?—Well, that would be half a million gallons.

5607. The results you told us just now were thoroughly reliable, being below the Mersey and Irwell standard with double contact, and were frequently up to that standard with single contact?—Yes.

5608. And you find that by mixing single contact effluent and double contact effluent you were able to bring about non-putrefactive mixture?—Oh, yes.

5609. You made the same experiment with Ship Canal water—putting the double contact effluent with an equal quantity of Ship Canal water, and you found that as a result there was purification in that volume of Ship Canal water?—That was so, even more than its own bulk could be purified.

5610. And I think you tried a very large number of samples?—Oh, yes, day by day for several months.

5611. So that the conclusion you came to is one in which you have complete confidence?—Absolutely.

5612. And it points to this, does it not, that these effluents had within them the elements of further purification?—Certainly.

5613. And were not liable like certain chemical precipitation effluents to secondary decomposition?—Not at all. I have on the walls charts showing these tests if the Commissioners would care to see how they have varied.

5614. We have already before us, and most of us have studied the very full details you have given us on that point; I think we need not spend any more time on it. Now we come to the very important question as to whether seeing you can obtain good results as to the quality of the effluents by this system of bacterial treatment you can also maintain the capacity of your beds. You have no doubt analysed your filtrates with the view to ascertaining the quantity of suspended solids in your filtrates?—Yes.

5615. And I think you analysed the sludge left upon the beds—on the primary beds; did you analyse any of the matter which was left behind?—We have analysed the suspended matter which went upon them.

5616. You did not analyse any of the sludge which was on the surface of the primary beds, did you?—No; as a matter of fact we have never had any actual sludge with the exception of that we got upon the surface of the bed accidentally the other day; nothing that you could really call sludge except a certain amount of suspended sludgy matter in the channels; that has been analysed.

5617. I think you have no doubt that part of the suspended matters are indigestible by bacteria?—No doubt whatever.

5618. As they do not come out with the effluent, they appear to remain behind?—Undoubtedly.

5619. And unless they remain behind on the surface of the bed where they can be removed they are irremovable?—They are irremovable.

5620. Then you would expect to find a gradual silting up of those beds, unless you can succeed in keeping these indigestible matters on the surface of the beds?—That is not necessarily so, I think, if I may speak with due deference, inasmuch as the suspended matter itself has a certain water holding capacity; that is to say that you could imagine that you could get a certain amount of sand and grit, and so on, which would fill up the large interstices of your filter to such an extent that no more would get down, but I think suspended matter itself would have a water capacity, smaller no doubt than the original material put in, but still a definite capacity till you might have nothing but a sand filter throughout. So far as that was concerned the character of such suspended matter would depend upon the particular district in which the works were situated.

5621. But if that matter got down into the body of the bed it must to that extent reduce capacity?—To that extent.

5622. Now, you noticed at first with all your experiments with contact beds an early rapid reduction of capacity?—Always.

5623. Which you attribute no doubt rightly to a settlement of the material?—Very largely, and also the bacterial growth. On opening up a filter the material is seen to be covered with a jelly-like growth, presumably of organisms.

5624. So that the early reduction of capacity is due to consolidation, and to the formation of this slimy mass upon the surface?—And also no doubt to a certain amount of suspended matter getting in; those three things at the beginning.

5625. Now the vital point is to know whether you can, after making allowance for this early and inevitable reduction of capacity, maintain the capacity of your beds for a sufficiently long period. You have found, have you not, a tendency to accumulate, and with a view to avoid that you have used fine material on the surface of your bacterial beds, such surface to act as a strainer, and to keep back the solids?—That is our intention, yes.

5626. Well, now, how far have you been successful in keeping upon the surface of the bacterial beds indigestible solids?—If we confine our attention to septic tank effluent, as I presume you want to do.

5627. Yes; we are speaking of that only?—The beds connected with the septic tank have been working for eighteen months, and the surface has risen some six inches above its original level, and the capacity of those beds has not yet become, or only at the present moment is it about equal to one-third the original capacity.

5628. When you say one-third the original capacity you do not mean one-third of the water capacity, but the capacity before the material was put in?—Yes.

5629. In this case, therefore, you are alluding to one-third of 10,000?—No; in the case of the septic tank bed the original capacity was not 10,000.

5630. I beg your pardon, I thought you were alluding to those?—The filters; I have not noticed the A, B, C, and D filters; I am bound to say I have not noticed that same piling process, and I do not quite understand the reason why that is so, and in the case of A and C beds the capacity has gone down more than in the case of other beds that we have been experimenting with.

Mr. G. J. Fowler, M.Sc. F.I.C.

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5631. The original capacity of those beds was 10,000?—Of those beds.

5632. A, B, C, and D?—Those were all 10,000 originally.

5633. And the three you have given me was 3,333?—Yes.

5634. What is the present capacity of A, B, C, and D? I can give you those exact figures. The present capacity of A is 2,280, of B 3,510. That is above one-third, although B has been working for nearly a year as a primary filter; and C is 2,480, and D well, of course, we took a foot away from the top of D, but practically our measurements show that there is very little loss of capacity there—that is beyond the initial figures.

5635. Then A and C have fallen below the one-third? A and C have fallen below the one-third.

5636. Do you expect to recover them up to the one-third?—I am a little doubtful whether we shall do it, unless we give them a very long period of rest. They taught us this lesson, that it is necessary to rest your beds frequently. If you allow them to decrease below a certain limit it takes a proportionately longer time for them eventually to increase in capacity. They have increased, I may say, considerably. We got them down so low as about 1,500, and they have increased by 1,000 gallons, and these figures that I have given you are not dry capacities, they are all measured under working conditions. They have increased from a net capacity of 1,500 up to 2,500. Of course, we had worked them for six months practically at four fillings a day with very little rest; if we had worked them more steadily, and never allowed them to go down, then I think we should have been able to get them up as we have got B up, as B has been working in the same manner as the others, only we have never allowed it to go down quite so far, and you will see the capacity now is considerably more than it was some time ago, and is more really than one-third. No doubt if we give these two beds six months rest, or something like that, we could pick them up very considerably, but the plan seems to be never to allow them to go down, to give them frequent periods of rest and never over work them.

5637. So watch your beds that you never let the capacity get too low?—So watch your beds that you never let the capacity get too low, that is I think what you should do.

5638. Now, this bed B, you tell us you have been working very hard lately as a single contact bed, dealing with septic effluent?—Yes.

5639. It would be interesting, I think, to know to what extent you did work it?—We worked it from the date that we began to work A, C, and D together; ever since then B has worked as a first contact bed; and has been worked as such ever since. It was worked from October 5th, 1899, to February 23rd, 1900, as a primary bed, four fillings per day, except Sundays, and during that time the average quantity dealt with per acre was 1,270,000 odd gallons, that is, of course, working it really much harder than we should propose to work it under the best practice, and under those circumstances only 16·3 per cent. of the samples were putrefactive.

5640. And the capacity of that bed has been maintained without your doing more than raking over the surface?—That is all we have done.

5641. There has been no reconstruction during that period?—No, with the exception that quite recently—within the last day or two we have taken off the top six inches, and put finer material on; that is all that has been done.

5642. There is, I suppose, a certain risk in coming to any final conclusions upon which to base a scheme of sewage treatment for Manchester upon experiments upon so small a scale?—There is, no doubt, a certain risk. One has to estimate the effect of certain points on the large scale. That is always what we have tried to do. We have always endeavoured, if I may use the expression, to think in the large, though we had to work in the little.

5643. In those beds A, B, C, and D you have sloping sides, which give the full depth of the bed to only a very limited area in the centre?—Well, the area is perhaps hardly so very limited, that is to say, there is 17 feet in diameter—a square of 17 feet.

5644. Which is the full depth?—Which is the full depth, yes.

5645. But you are at the present time constructing a contact bed of a very much larger area?—Yes.

5646. When do you expect that bed to be actually at work?—It is a little difficult to say; it depends on how we can get material. Certain iron work has to be ordered, which may delay matters, and also it may take some time to gather and screen cinders, but we hope to be working in the autumn.

5647. What is the area of the bed you are constructing?—There will be two beds, each of half an acre.

5648. So you will have one acre on which to make experiments?—Yes.

5649. And what is the nature of the material you are proposing to use?—We shall use very rough material over the drain pipes; the bulk of the material will be such as is retained by one-eighth mesh; that is to say, practically ordinary cinders with anything below one-eighth inch mesh screened out; the whole thoroughly mixed, and then we shall have about six inches of screenings on the top.

5650. Then so far as your experiments have gone, Mr Fowler, with these small experimental beds you have formed the opinion that it is practicable, dealing with Manchester septic effluent, to maintain the capacity of those beds for a sufficiently long period to make it financially practicable to adopt that system?—That is my opinion after careful watching.

5651. It is a delicate operation which requires careful watching?—There is no doubt whatever about that.

5652. Have you formed an opinion as to the acreage that would be required based upon your experience for the treatment of the Manchester sewage?—It would a great deal depend upon how the acreage was laid out.

5653. What is in fact the acreage recommended by your experts?—60 acres of beds for the ordinary sewage, and 25 acres for storm beds.

5654. 25 acres for storm beds?—In addition, yes.

5655. Would those storm beds be constructed in any way like the one which you showed us to-day, a simple bed constructed cheaply with 18 inches of cinders?—18 inches to two feet, that is our idea, constructed simply on those lines; perhaps a little better than that you saw to-day, but much according to those lines.

5656. The result you obtain from those beds, is that you may overwork them for a time during storm times, provided you give them ample rest after those periods?—That is so.

5657. And the effluents you obtain have not been putrefactive?—We can fill them twice a day with ordinary sewage with the certainty that they will not be putrefactive. We have not made sufficient experiments with storm sewage to make us quite certain how many times we can fill them rapidly under those conditions.

5658. The first dilution after rain is very bad indeed, is it not?—Yes.

5659. Worse, in fact, than your normal flow of sewage?—As regards suspended matter.

5660. Worse than the normal flow of sewage generally?—Not necessarily so, but there is a greater increase in the suspended impurities than in the dissolved impurity, I should be inclined to say, though it varies. There is, perhaps, no absolute rule even in that respect.

5661. Seeing that the early dilution of sewage is very bad, there ought not to be any increased burden of work thrown upon the bacteria beds until after the first dilution has passed?—No.

5662. In other words, the area which you calculate for your beds, should be based not upon your normal flow, but upon your normal flow plus that first dilution?—Yes, reckoning storm beds and all included, and also additional tanks.

5663. Do you not think that the first dilutions should be dealt with by the same thorough process as the normal flow?—To be thoroughly adequate, I think, yes, it should be.

5664. The later dilutions, of course, are very weak in impurities, and may be dealt with in a special way?—Just so. If I might be allowed one moment there, it is possible, that by mixing the filtrate from subsequent processes, that although perhaps one contact would not be enough to purify your first flow, yet the filtered effluent which comes immediately afterwards would be so good that the mixture of the two would give you adequate purification.

5665. It is an interesting suggestion; that, of course, is borne out by your experiments of the Ship Canal mixtures?—Possibly this would be the place just to make that point rather strongly, as I should wish to do, that I do feel that there is a possibility of utilising this residual power of self purification in certain effluents, to continue itself subsequently, especially if the mixture is exposed, as far as possible, to air, say through a culvert or some channel where it might be dashed together. You have all the factors there for the simple purification of sewage by the addition of air, the filtrate being as it were, inoculated by the nitrifying bacteria. That seems to me to be the direction in which we should look for some progress to be made.

5666. Your experiments have been confined to contact filtration; you have not, I believe, as yet made any experiments in continuous filtration of septic effluent over coarse material?—Not over coarse material.

5667. I believe you are about to make some experiments of which you will tell us later on. The questions I have asked you have been to get on our Minutes a statement of fact. I have avoided asking you critical questions as the Commissioners will have you before them again, when they will have an opportunity of probing in various directions the evidence you have put before us. I personally thank you for the way in which you have answered those questions, and for the ready information which you have at all times placed at our disposal. Does any member wish to ask you any questions? (After a pause.) We thank you, and I do not think it is necessary that we should call Mr. Wilkinson, or that we should trouble Sir Bosdin Leech with any questions. The ground has been gone over very carefully by Mr. Fowler, and I think will serve our present purpose.

(*Sir Bosdin Leech.*) There are a number of diagrams here.

(*Witness.*) There is rather an interesting series of storm curves here. We have a curve of the maximum storm which we have ever had at Manchester at the melting of the snow.

5668. How many volumes is the maximum; how many dilutions of the normal flow do you obtain at the works?—We have had a rate of 200,000,000.

5669. But that is only for a very short period?—That is only for a very short period. There you have 90,000,000 continuing for two days; an average for two days.

5670. Then, are we to take it, Mr. Fowler, that the maximum you have met with for a lengthened period has been three times the normal flow?—Three times the normal flow, distinguishing, that is to say, between that and absolute flow, as I would call it, but we have had up to 200,000,000 gallons, at that rate that is, or six times—over six times 30,000,000 you see.

5671. But, surely, heavy rains lasting two days or lasting three days would give you more than three dilutions, would it not?—Not on the average.

5672. Then we must infer that the storm overflows come into operation at three times?—Well, our experience is that they operate adversely to us; that they let in river water.

5673. Anyway, as a fact, you do not receive at the works at any time more than three dilutions except at very short periods?—Only at very short periods; the maximum storm we have record of, you see from these being three times 30,000,000. Of course I must always distinguish between the 30,000,000 and the forty gallons per head; including, of course, subsoil water, we should often have as much as 60,000,000, you see.

5674. The country comprised within the City of Manchester is very flat?—Yes.

5675. And you have at all times subsoil water?—I think so.

5676. (*Major-General Carey.*) The dry weather flow includes the trade water?—Includes the trade water, yes.

(*Sir Bosdin Leech.*) A question was asked about the population; it was given as 530,000. I should like to amend that, I see it is 555,910; I take it that that is the last census.

(*Chairman.*) The 530,000, which I took from your own documents, was probably the last census, and the 555,910 is the estimated population.

(*Sir Bosdin Leech.*) 555,910 is, no doubt, the estimated population. The expenditure on sewage works by Manchester has been £818,035 11s. 8d. You asked a question at the works what the expenditure was, and I told you 30s. per head, divided as follows: Intercepting sewers, £594,972; tanks, etc., £50,805; filter beds, £1,393; land, £43,831; under-drainage, etc., of land, £12,448; steamer, £24,837; contingencies, £89,740; making a total of £818,035.

5677. And what is the annual cost to the citizens of Manchester in connection with the treatment of sewage? £13,206. That includes precipitation and chemicals.

5678. And interest on outlay at Davyhulme?—This does not include the interest; that is the actual expenditure, sir.

5679. The expenditure at Davyhulme is £13,000?—£13,000 for precipitation and chemicals, sludge disposal and filtration.

(*Witness.*) That is exclusive of interest on capital.

5680. What I want to get at is, what is the total cost inclusive of interest on original outlay at Davyhulme; what is the total cost to the citizens of Manchester of the disposal of sewage——

5680.* (*Sir Bosdin Leech.*) The sum would depend on whether you include the Davyhulme expenditure or the whole expenditure.

5681. I want the whole of the expenditure to the City of Manchester for sewage disposal?—Not including the sewers?

5682. I do not want the cost of sewering the city; expenses in connection with sewage disposal?—That comes to £218,000 to be added roughly; the interest on £218,000.

5683. To be added to the £13,000?—Yes.

5684. £218,000; we take that at £7,000?—Well, roughly between £7,000 and £8,000.

5685. That means £21,000?—If you put interest and all you may very fairly put £20,000 a year.

5686. About £20,000 a year is the cost of sewage disposal at Manchester?—Yes.

5687. (*Mr. Killick.*) As Mark Twain says, as far as you have got?—As far as we have got.

5688. (*Chairman.*) I think what Mr. Killick means is that for that cost you accomplish purification of 50 per cent., which is not very much.

TWENTY-THIRD DAY.

ACCRINGTON.

Friday, 27th July, 1900.

PRESENT:

Colonel THOMAS WALTER HARDING (in the Chair)

Major-Gen. CONSTANTINE PHIPPS CAREY.

Mr. F. J. WILLIS, *Secretary.*

Mr. C. J. WHITTAKER, called; and Examined.

Mr. C. J. Whittaker. 27 July 1900.

5689. (*Chairman.*) You are the chairman of the Accrington and Church Outfall Sewage Board?—Yes.

5690. And you have been connected with these works since?—Nine years; this is my ninth year.

5691. What is the combined population with which you deal?—54,000.

5692. What is the volume of sewage?—1¼ million gallons.

5693. Normal dry weather flow?—1¼ million gallons.

5694. To what extent do you receive storm waters?—Three volumes on to the works.

5695. You receive three volumes and deal with three volumes in the first process?—Through the tanks.

5696. What is the nature of your sewage; is it purely domestic sewage?—Purely domestic; we have a local currier—not a tannery, but just a currier, and a few small dye works and soap works, but the amount of trade pollution is very small—and a brewery, yes.

5697. And have you not a bleach works?—Yes, but we do not receive the trade refuse.

5698. And in connection with the dye works, I understand the dye refuse does not come into your sewers to any great extent?—No.

5699. Is it substantially correct that your sewage is domestic sewage?—Is domestic sewage.

5700. Now the treatment which you have adopted here is that of septic tanks followed by continuous filtration?—Yes; open septic tanks.

5701. Followed by continuous filtration?—Yes.

5702. The total area of your septic tanks is 1,800,000 gallons?—The present working amount, do you mean?

5703. The total capacity of your septic tanks?—1,800,000 gallons.

5704. And you work these septic tanks more or less in series?—Yes. The first four are in series; in the first two one tank receives 1,000,000 gallons, and any excess of flow passes into the second; the third and fourth are in series; four and five practically receive the same effluent.

5705. Four and five?—Yes, equally distributed.

5706. It is five and six, is it not?—Five and six, yes.

5707. Then it has not been practicable for you to try these six septic tanks as independent septic tanks?—No, impossible for us to try the experiment.

5708. Then you are unable, from your experience, here to point to any advantage or disadvantage in working septic tanks in series or separately?—Only that in attempting to work the first two tanks uniformly we had the difficulty of the removal of the sludge. At the present time we have the bulk of the sludge in one tank, and those two tanks can be changed. That is then the first now, but we can, just as readily, make number two number one—that is, we can change them about.

5709. Number one and number two are primary tanks?—Are primary tanks, yes.

5710. And you get the denser sludge in those?—In one of those two. When this is emptied out this will become the second tank.

5711. Then I may take it, Mr. Whittaker, from your experience here that it is convenient to work septic tanks in series?—Most convenient, chiefly from the point of view of removal of the sludge.

5712. If you remove this denser sludge from the earlier tanks of a series you find, I suppose, that in the later tanks there is very little accumulation of sludge, and removal of sludge from the later tanks is only required after very long intervals?—That is so.

5713. Now, have you found any advantage by working the tanks in series in this respect that you obtain less solids in suspension in the final effluent than you would do if each were worked independently?—Yes, I believe that is so.

5714. You think that you can obtain, working them in series, a reduction in the solids in suspension in the final effluent?—In the tank effluent and also in the final effluent.

5715. Now, can you give us any idea of the strength of your sewage; what are the figures in chlorine?—The average is about 10, the average over a long series of experiments; the chlorine test is 10—that is parts per hundred thousand.

5716. Per hundred thousand?—Yes.

5717. Then can you give me any idea of the suspended solids in your crude sewage?—In the crude sewage—the total solids in the crude sewage 67.

5718. I want the suspended solids?—The total suspended solids 67.

5719. Then you obtained that result over a considerable number of analyses?—Yes, from April to September.

5720. Over a period spreading from April to September of last year?—Yes, 1899.

5721. Now give us some idea of the tank effluent?—The total suspended matter in the tank effluent is about 18; take an average figure, 17.8.

5722. Is that per hundred thousand?—Parts per hundred thousand.

5723. Now what purification do you obtain upon the crude sewage in the tank effluent?—You mean on the albuminoid ammonia.

5724. As measured by albuminoid ammonia or oxygen absorbed?—Eighty per cent.

5725. Eighty per cent. in what?—Eighty per cent. on the albuminoid ammonia.

5726. You mean in the passage through the septic tank?—Through the septic tank is 67 per cent. Are you referring to the final effluent or the tank effluent?

5727. What I want to know is, what does the series of the septic tanks accomplish?—An average of 50 per cent. purification. Tank effluent on the crude sewage is 50 per cent.

5728. Roughly?—Roughly 50 per cent.

5729. Both measured by albuminoid ammonia and oxygen absorbed?—Both measured by albuminoid ammonia and oxygen absorbed, and even suspended matter.

5730. Suspended matter is much more because you told us it was 67 to 17?—That is included, you know, in the analysis. The amount of purification shown is 50 per cent. That calculates everything, both matters in solution and matters is suspension.

5731. What is the depth of the septic tanks?—Eight feet; the whole of them.

5732. You do not think that the depth of the septic tanks matters very much; it might be increased, according to local circumstances, to 10 or 12 feet without disad

vantage, or for that matter with advantage?—With advantage.

5733. Merely as regards storage—not as regards septic action?—The tanks could be run much longer with the deep tank than with the shallow one.

5734. That is a question of storage?—It is a question of storage.

5735. But you find eight feet is sufficiently deep to give the necessary chemical changes?—Eight feet we have found to answer very well indeed, while six feet have been a failure. I have had experience of a six-foot tank which has been found to be too shallow.

5736. Why, what was the result?—The tanks were silted up before the septic change taking place was sufficiently advanced.

5737. Then do you think that there would be any advantage in having deeper tanks than eight feet in this respect, that possibly with the deeper tanks you might have less suspended solids coming out in the effluent?—No; I think the advantage of a deeper tank would be in having less surface exposed to the air. They would be better covered, and there would be less nuisance from any smell that might arise from them; the gases would be more confined.

5738. But surely the gases do not get stored underneath the scum?—Oh, yes.

5739. Well, there cannot be any accumulation of gases under the scum. If gases are produced they must come out, whatever the depth?—Yes. Then you have less surface for them to be spread over; they would be more concentrated at any one point.

5740. At any one point?—And the question of temperature, there would be less surface exposed to the air.

5741. But the value of the scum, at all events, is certain in this direction, that it conserves the heat in the sewage?—Yes.

5742. Now comes the important question as to the digestion of solids in the septic tanks; have you been able, from your experience in Accrington, to form any estimate of the proportion of sludge digested by the tanks?—Only so far as is compared with chemical precipitation.

5743. But in chemical precipitation you had a large amount of precipitant put into the sewage, which, of course, was added to the sludge?—Yes.

5744. Have you taken that into account?—Yes.

5745. Then how do you form an estimate of the consumption of sludge in the septic tanks?—I do not think there is an actual consumption of sludge in the septic tank; that it is only changed in character.

5746. Do you suggest that there is no reduction of sludge?—Absolutely no reduction of sludge; the same amount of sludge, the balance of the total solids sent away in the effluent remain on the works.

5747. I think we are misunderstanding each other, Mr. Whittaker. You have 67 grains per 100,000 in your crude sewage?—Yes.

5748. You have 17 grains per 100,000 coming out with the tank effluent?—Yes.

5749. Do you mean to say that you remove as sludge from the tanks the balance between those two figures?—Yes.

5750. And that there is no consumption by septic action?—No.

5751. Then what is this evolution of gas which we see taking place; does not that mean a digestion of solids?—I mean with the exception of the gas which is generated—that is a measurable quantity and is immaterial, because the oxygen absorbed is quite equal to the gas evolved, and the final effluent contains quite as much extra oxygen as gas evolved in the tanks.

5752. Then are we to understand that it is your opinion that in using septic tanks we shall have just as much sludge as we should have by natural sedimentation?—Yes. My opinion now, after the experience I have had with them, is that the action of the septic tank is to enable the tank effluent to be dealt with by an aerated filter, and that it is only the change in the character of the tank effluent that permits of its purification by means of an aerated filter.

5753. Then if other authorities who have experimented with septic tanks report to us that they find there has been by the septic tank a consumption of suspended solids to an extent varying from 40 to 60 per cent. you conclude that they have made a mistake?—I should say that they had made a mistake, yes; and that is the only point in my previous evidence that I should wish to modify.

5754. Then why should you not here utilise a much smaller area of tanks and rush your sewage faster through it?—The change would not take place in the sewage that would allow of it to be purified by an aerated filter. Fresh sewage cannot be treated with one of these filters.

5755. What leads you to say that fresh sewage cannot be treated by one of these filters; have you tried any experiments in filtering in this way?—Well, I have had opportunities at Morley of noting that fresh sewage cannot be treated by these filters.

5756. But at Morley you had to deal with a sewage mixed with a considerable volume of trade effluent?—Yes; but we could make it septic; that is, it became septic on long standing. Most effluents, whether trade or otherwise, can be made septic if the capacity of the tanks is sufficiently large.

5757. Then we are to take it from you that you are producing here just as much sludge from your septic tanks as you were producing before from chemical precipitation except for the difference of the volume of precipitants that you put into the sewage?—Yes. It is of a very much handier kind, more easily dried and easier to deal with.

5758. I should like, as the point is very important, in regard to consumption, if any, of solids by septic action, to know from you on what grounds you base that conclusion. Have you carefully estimated here the volume of sludge produced over a considerable period by your septic tanks?—I have measured the quantity for twelve months, the whole of the sludge that has been produced on the place for twelve months, which amounted to 320 tons.

5759. But was this 320 tons produced from the septic tanks?—From the septic tanks.

5760. Well?—Why I make the observation that there is no diminution in sludge is that we send such a small quantity away in the effluent; the balance must be on the works, between what we send down the river and what we receive at the works, you may call it a theoretical consideration if you like; we only send so much away in the final effluent; we receive so much on the works; the balance must be on the works with the exception of what is sent away in gases.

5761. Have you made a calculation based upon this, Mr. Whittaker? You told me that the average of suspended solids in your sewage is 67 grains per 100,000?—Yes.

5762. That the average in the effluent from your tanks is 17 grains per 100,000?—Yes.

5763. Therefore one may assume that 50 grains per 100,000 is left behind in the tanks?—Yes.

5764. Now have you made any calculation as to what amount of sludge that 50 grains per 100,000 would represent calculated upon the total volume dealt with over a lengthened period?—Yes, it corresponds very much with the actual quantity of sludge removed within about 30 tons.

5765. I think I will need to press that further?—I should call the anaërobic tank a disintegrating tank in which the matters which can become putrid and mineralised; that is the only term I can use where matters which can, become putrid, become mineralised.

5766. And you do not consider the great evolution of gas to represent the chemical change transforming the solids into gaseous and liquid products?—Only mineralising them, and that the amount of gas absorbed is quite equal to the amount of gas evolved.

5767. Well, now, your process consists in the first part of septic action, and, secondly, of continuous filtration over coke beds. Your coke beds at the present time are 10 in number?—Yes.

5768-9. And they are of a diameter of 61 feet?—Six of them are 61 feet in diameter, and four of them are 45 feet in diameter.

5770. And what is the depth of them all?—They are all one uniform depth—nine feet; nine feet of filtering material.

5771. And the material itself is coke which has been rejected by a two-inch screen?—Unbroken gas coke which has been rejected by a two-inch-mesh screen.

5772. And the distribution over the bed is by means of sprinklers?—Is by means of sprinklers.

5773. And the sprinklers are fed by pulsometers?—

Mr. C. J. Whittaker. By pulsometers. Each of the sprinklers on the 61-foot bed is operated by one pulsometer.

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5774. I understand that you consider that the use of the pulsometer is of advantage in two ways; first, that it increases the heat of the sewage by some five degrees, and the other that the pulsating action of that pump tends to clear more readily the holes of the sprinkler?—Yes; to keep the pipes thoroughly cleansed, at the same time there is discharged on the filter along with the sewage almost the same volume of air; each of those orifices in the spray is a mixture of air and sewage.

5775. But that would be the case if you pumped the whole with an ordinary pump?—Instead of with the pulsometer?

5776. Or if it flowed on to the sprinkler with a natural head?—That would not take place.

5777. Why not?—Because the pump is operated in such a way that at the same time that it is drawing sewage it also draws air; it draws them in about equal quantities and discharges them together on to the bed.

5778. Then the question arises at what cost do you bring about these results? I understand you have here one boiler?—We have here one boiler about 28 feet by 7 feet 6 inches.

5779. Is the boiler used for any other purpose than that of feeding the pulsometers with steam?—No other purpose.

5780. Then what is the annual consumption of coal?—At the present time in dealing with 1¼ million gallons the consumption of coal is £60 per month; £720 per annum.

5781. That is the cost?—Yes.

5782. You are spending £720 per annum in coal?—In coal.

5783. To deal with 1¼ million gallons of sewage?—Yes. That provides steam for actuating the pulsometers and for lifting the sludge from the lower settling tanks. That is the very last estimate including total cost.

5784. I understand that at one time you proposed to inject steam in addition to the heating effect of the pulsometer; do you do that here?—We have not found that necessary during the past twelve months.

5785. You have had no trouble by the pooling of the sewage on the top of the filters?—None whatever.

5786. Your filters work as freely now as when they were started?—Yes.

5787. And I understand one quarter of them have been working for two years?—For two years.

5788. And that the remainder have been working from ——?—From twelve to three months; these would be the top ones here.

5789. And there has never been any digging over?—No raking, no forking, no disturbance whatever of the surface.

5790. You have not been inconvenienced by the presence of any growth on the surface?—None whatever.

5791. Now, Mr. Whittaker, what kind of results have you obtained in regard to purification by the use of the filters?—The average of a number of analyses has given us in the final effluent 64 per cent. on the tank effluent, and 81 per cent. of purification on the raw sewage.

5792. As measured by what?—By the albuminoid ammonia.

5793. That includes the solids in suspension in the final filtrate?—Yes, everything.

5794. Then what in regard to the oxygen absorbed?—The oxygen absorbed gives 66 per cent. and 81 per cent.

5795. Sixty-six on the tank effluent and 81 on the raw sewage?—81 on the raw sewage. The 65 per cent. of purification is including all the suspended matter, and 76 per cent. with the suspended matter removed. That gives the amount of suspended matter.

5796. The earlier part of your answer, may we take it, was correct?—Yes.

5797. It has nothing to do with the tank effluent and the sewage?—The tank effluent, but not the raw sewage.

5798. The purifications you have given us are figures showing the purification on the tank effluent as measured with and without suspended matter in the filtrate?—Yes; 64·4 and 76.

5799. Then what is the purification obtained on the raw sewage by the double process expressed as measured with and without the suspended matter in the filtrate?—On the albuminoid ammonia.

5800. You gave us that before did you not?—Yes, but this is on the raw sewage.

5801. Yes?—On the raw sewage 81 per cent., but it does not refer to with and without the suspended matter —81 per cent. including the suspended matter.

5802. Then you have not the percentage purification without?—No; purification on the crude sewage 81 per cent.

5803. Including suspended matter in the filtrate?—Yes.

5804. Now you have a considerable amount of suspended matter in the filtrate?—Yes.

5805. What would it average per 100,000?—The suspended matter?

5805. In the filtrate; what would the suspended matter in the filtrate average?—Four parts per 100,000.

5807. Then, in consequence of pressure from the Rivers Authority you find it necessary now to have some settlement after filtration?—That is so.

5808. And I understand that the matter so settled out is not putrefactive?—That is so.

5809-10. And is largely mineral?—58 per cent. of the suspended matter is mineral.

We thank you, Mr. Whittaker, for your evidence.

Mr. W. J. Newton, called; and Examined.

Mr. W. J. Newton. 5811. You are an Associate Member of the Institute of Civil Engineers?—Yes.

5812. And you are the Engineering adviser to this Board?—Yes.

5813. You superintended the construction of the filters in connection with this scheme?—I did, sir.

5814. The last set of filters constructed were six?—Six, yes.

5815. Can you tell me what was the cost of the last six constructed?—I cannot give you the cost.

5816. Can you give me the total cost?—No.

5817. But you could send it to us?—Yes, with pleasure, sir.

5818. You will be good enough to do so?—Yes.

5819. Have you formed any estimate of the cost of the material per cubic yard?—For filter material?

5820. The coke that you have used?—About 10s. 6d. per cubic yard.

5821. About 10s. 6d. per cubic yard is the cost of the coke?—The cost of the coke.

5822. Apart from any labour?—No, that is laid in the filter complete.

5823. I see you are constructing a group of four filters at the present moment?—Yes.

5824. You are surrounding those filters with pigeon-hole brick walls?—Perforated walls, yes.

5825. And you are laying at the bottom of the filters a concrete layer covered by half-round drain pipes, 18in. in diameter, perforated with holes about 2in. in diameter?—Yes.

5826. Have you formed any estimate of the cost of this new set of filters?—I can give you the total cost, but the total cost per square yard of filter I cannot give you at the moment.

5827. But the cost of these four filters, have you any estimate of what it is likely to be?—I have an estimate I can give you.

5828. What is your estimate?—I think you can take the estimate as fairly correct, too.

5829. What is your estimate of the total cost of this group of four filters?—Had you better not take the ten, sir, because the estimate is for the ten.

5830. Very well, the ten?—£11,205.

5831. That includes a boiler?—Yes, and economiser.

5832. And the necessary pulsometers—the whole thing complete?—The whole thing complete, yes.

5833. What is the total area of the ten filters referred to?—3,800 square yards; in addition there are four older filters working with an area of 967 square yards.

5834. And what is the diameter of each filter?—The large beds are 62 feet, the sprinklers may be 61 feet.

5835. These ten sprinklers are of an uniform diameter of 61 feet?—61 feet, sir.

5836. And the depth of these filters?—Nine feet.

5837. Nine feet of coke?—Of coke, yes.

5838. I should like to ask Mr. Whittaker another question. You think it is necessary working filters on this system to use very coarse material?—(*Mr. Whittaker.*) Yes, not smaller than two inches.

5839. You are anxious that solids should not remain in the filter?—It is very desirable that they should not be allowed to pass through when an equilibrum has been reached.

5840. And do you think that at the speed of 400 gallons per square yard, which, I understand, is your constant speed here, any important accumulation takes place in the filter?—We think we have reached the point where no serious accumulation takes place in the filter.

5841. Now, if accumulation takes place, would you expect that in times of storm if it were possible to pass a larger volume over the filters such accumulations would be washed out?—Yes, I believe such accumulations could be washed out, and would be washed out.

5842. In fact, by holding the sprinkler, and causing the flow to pass over part, and not the whole of the filter, you wash out such part?—Yes.

5843. Have you paid any attention to the action of such iron as is in the sewage upon the purification?—No, the quantity of iron is so small that we do not think that we can take it into account. We have no iron only such as is found in ordinary sewage; we have no special trade iron.

5844. You have told us, Mr. Whittaker, what are the percentages of purification that you obtain, but could you give us the figures of a typical average analysis of the filtrate with and without suspended solids?—Taken from the weekly averages from January to the 21st June, the albuminoid ammonia—the average of the whole period is ·22.

5845. Inclusive of suspended solids?—Inclusive of suspended solids.

5846. What is it exclusive?—·121.

5847. Per hundred thousand?—All in parts per hundred thousand.

5848. Then the oxygen absorbed?—The oxygen absorbed; he has not averaged that, but these are all weekly averages, and they vary from ·75 to 1·4. *Mr. W. J. Newton.* 27 July 1900.

5849. And what is the average figure relating to nitrates?—About 2·2, it varies from 1·3 to 2·6 — 2·2.

5850. And your suggestion is that, although these results are distinctly above the Mersey and Irwell standards, they are perfectly satisfactory results, because of the large quantity of nitrates in the filtrates?—Yes, I think so. I think that the nitrates ought to be taken account of in judging of the quality of the effluent.

5851. Just one other question; you have tried a small experiment with second filtration on the same system of the filtrate produced by the large filters?—Yes.

5852. And you have carried out the second filtration for the purpose of obtaining purer water for the supply of your steam boiler?—That is so.

5853. Have you any figures showing the result of this double filtration?—Yes, albuminoid ammonia is reduced to ·03 or ·025 parts per hundred thousand, and the nitrates go up to 3·6. These figures are not higher than the Mersey and Irwell standard, because these figures are given in parts per hundred thousand, and in the Mersey and Irwell standard, the figures are given in grains per gallon.

5854. You mean that the figures with regard to the nitrate, minus the suspended matter, are not above?—Including the suspended matter. Mr. Scudder has already had under observation one of those filters, and he has announced in the Court that the effluent is satisfactory to be turned into any stream with results not so good as this.

5855. What was the figure that you gave me just now, in albuminoid ammonia?—·22.

5856. But that is over the Mersey and Irwell standard?—No, ·2 per hundred thousand.

5857. As a fact, you are above the Mersey and Irwell standard?—Yes, their official standard does not take nitrates into account.

5858. As a fact, you are above the Mersey and Irwell standard, but you say, notwithstanding that fact, the presence of nitrates makes your effluent a perfectly safe effluent to go into a stream?—Yes.

5859. But as a fact, you are above the Mersey and Irwell standard?—Yes.

Mr. Joseph Barnes, called; and Examined.

5860. (*Chairman.*) You are the superintendent chemist in charge of these works?—Yes.

5861. And you or your assistants make frequent analyses of the filtrates obtained?—Yes, daily analyses.

5862. You hand in to me now a summary of the January results?—Yes.

5863. And of the April results, and of the results from June 1st to the middle of July?—Yes.

5864-5. All of this year?—Yes. These are the monthly averages from daily samples. *Mr. J. Barnes.*

Average of Results, January 1900.

(Parts per 100,000.)

	Albuminoid Ammonia.	Oxygen Absorbed.	Chlorine.	Nitric N.
Raw sewage, settled	0·67	5·7	6·5	—
Tank effluent	0·58	4·9	—	—
Filter effluent	0·15	1·2	—	—
Filter effluent (suspended matter removed).	0·08	0·8	—	1·44

Average of Results, April 1900.

Raw sewage, settled	0·82	7·6	9·6	—
Tank effluent	0·95	9·1	8·9	—
Filter effluent	0·23	2·2	8·7	1·60
Filter effluent (suspended matter removed).	0·13	1·4	—	—

Average of Results, from 1st June to middle of July 1900.

Raw sewage, settled	0·90	8·0	10·4	—
Tank effluent	0·82	7·8	10·2	—
Filter effluent	0·29	2·6	10·2	—
Filter effluent (suspended matter removed).	0·16	1·5	—	2·9

TWENTY-FOURTH DAY.

Tuesday, 13th November, 1900.

PRESENT:

The EARL OF IDDESLEIGH (*Chairman*), *presiding.*

Sir MICHAEL FOSTER, M.P., F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. WILLIAM HENRY POWER, F.R.S.

Mr. F. J. WILLIS, *Secretary.*

Dr. HOUSTON and Dr. McGOWAN, recalled; and further Examined.

Dr. Houston and Dr. McGowan.
13 Nov. 1900.
Appendix No. 22.

5866. (*Chairman.*) Dr. Houston, you have come to-day to hand in that diagram (*Diagram exhibited*)?—(*Dr. Houston.*) I would like you to see the diagram; then Dr. McGowan might be able to draw a series of curves showing how far his chemical tests run parallel with my bacteriological ones, and then we could put those in; perhaps it would be more valuable if the two were handed in together.

5867. Would you mind just explaining shortly what the diagram shows?—The red line here represents enteriditis sporogenes.

5868. (*Sir Michael Foster.*) What is the scale?—This begins at 1,000 per c.c., and goes in successive tenths to none in 1 c.c., which is a very wide range. The green line is bacillus coli, also in one c.c. going from one hundred thousand or more per c.c. in successive tenths, down to less than one hundred per c.c., and in some cases B. coli was absent in one c.c. Then the blue line refers to this proposed gas test, where the scale goes from a positive result with 1-1000 c.c. down to a negative result in one c.c. You will note that the three are all comparable, they all go down in tenths. And the brown line there and there and there is a provisional standard. From here to here we are dealing with sewages, and you see that in all cases the tests correspond very nearly, and are a long way above the provisional standard.

5869. Are not those different sewages?—Yes, I think they are all different sewages.—(*Dr. McGowan.*) They are all different, yes.—(*Dr. Houston.*) Then these are effluents from various sources, and as you see from the diagram there are some above and some below the provisional standard, and the red, and the green, and the blue in nearly all cases correspond again. The advantage of this gas test is that it can be applied by anyone. It takes 24 hours, but it does not need to be observed during the 24 hours; you merely make a test and wait 24 hours, and then go and record the result. And it gives a wide range of results, since with sewage you get a positive result with so small an amount as one-thousandth part of a c.c., and with a good effluent you get none in one c.c., and with a pure water you may get no result even with as much as one hundred c.c. I have photographs to show that between crude sewage and pure water the difference may be one hundred thousand to nought, which is an extraordinarily wide range. I think it is important that it should show a range like that, so that you should be able to say not only that a particular effluent passes or does not pass, but by how much it passes, or how much it fails to pass, then you can compare different effluents at once.

5870. (*Professor Ramsey.*) Would you give an account as to how each of those different lines was obtained. I understand that the last line of all is by the gas test tube process?—This one (*indicating on diagram*).

5871. Yes. Would you mind describing the gas test tube process?—The best way to apply it is to take a number of test tubes containing the sterile gelatine, and then add to one one c.c. of the liquid to be tested, to the next one-tenth, to the next one-hundredth, and to the next one-thousandth. Then you melt the gelatine, shake up each tube, put it in cold water to let it get solid, then put it aside either in an incubator or in a warm room. At the end of 24 hours you observe it as regards gas production. I would like to show you these photographs. (*Photographs exhibited.*)

5872. (*Sir Michael Foster.*) These are all taken at an uniform temperature?—Yes, so as to get as exact figures as possible. I do not know if you can see these photographs from there, so I will explain them. Here is one of sewage having bubbles of gas with one-thousandth of a c.c.; in nearly all cases of sewage this occurs, and with a good effluent none in one c.c., and with a pure water you see from the photograph that you get none with as much as one hundred c.c. The bacterial contents of 100 c.c. are obtained by filtering 1000 c.c. through a Pasteur filter, and brushing the surface of the filter into 10 c.c. of sterile water; then each c.c. of the filter brushing is equal to 100 c.c. You see then in the photographs a negative result with 100 c.c. of pure water, and a positive result with a thousandth of a c.c. of sewage.

5873. (*Colonel Harding.*) One thousandth part of a c.c.?—Yes.

5874. (*Professor Ramsay.*) The middle line?—The middle line refers to bacillus coli. There are different ways of estimating that. Do you wish the particular method?

5875. Not necessarily, it is by a culture plan?—By culture, yes.

5876. What is the medium?—The most delicate way is by using broth in successive dilutions, and then making special culture from broth.

5877. That is the method you have adopted in drawing up that particular table?—This particular one, and enteriditis is here done in tenths. There is a great advantage in doing things in tenths, you can compare them so easily. You have a series of milk tubes, one containing 1 c.c., another one-tenth, another one-hundredth, and another one-thousandth c.c. With a crude sewage you get a positive result with one-thousandth c.c.; with a good effluent you do not get a positive result even with 1 c.c.

5878. (*Sir Michael Foster.*) What is the positive result?—Well, you get the typical appearance in milk culture.

5879. Milk culture?—Yes.

5880. It is not a question of the physiological effect?—Hardly, it is just the change. The great advantage of those tests is the wide range which they reveal between crude sewage on the one hand, and a good effluent on the other.

5881. The "gas" test is a question of observation of gas in gelatine culture, is it not?—Yes.

5882. But enteriditis, the biological effect in milk culture, not the counting of colonies?—Yes, that is why you do it in tenths. You get a positive result, say, with which enables you to say there were present at least 10, but less than 100 c.c.

I have not put the total number of bacteria on this table, I thought it would confuse it; but I think the figures run very fairly with those.

5883. The conclusion being that the gas test will give a very good view of the presence of bacillus coli and enteriditis?—Yes, besides giving you a good idea of the number of gas-forming putrefactive bacteria present.

5884. (*Mr. Power.*) Chemically, are there any observations parallel to that in any way—the same sewage and the same effluent, above or below the provisional mean?—(*Dr. McGowan.*) Yes. I went carefully through the chemical results; and, in fact, I put down some notes, and sent them to Professor Ramsay, but unfortunately he has not yet received them. However, I remember the points; they were shortly these: That when you are dealing with a sewage or bad effluent on the one hand, or with a very good effluent on the other, the results agreed perfectly with Dr. Houston's gas test; but when you came to an effluent of which it required

say, one-tenth c.c. to give gas, then the results wandered about, and became uncertain. In addition to that, there were one or two other very interesting points came out. We had some effluents from the Aldershot Camp Farm—effluents from exceedingly strong sewage—and the effluents themselves contained as much organic nitrogen as 0·4 or 0·6 parts per 100,000, which is a very large quantity, of course; but, at the same time, they contained much nitrate nitrogen, *i.e.*, from 1·6 to 2·6 parts per 100,000, or something like that. Those effluents, as I was saying to Mr. Killick a little while ago, would be condemned out and out by the Mersey and Irwell standard, but yet on incubating them in my laboratory, they kept perfectly sweet, because they contained this large reserve of nitrate to draw upon. And the interesting point was that with these effluents Dr. Houston got no gas with 1 c.c., or even more than 1 c.c.

5885. Those particular effluents?—Yes, those particular effluents. It is only fair to say there was a certain amount of contradiction in the results from some further Aldershot Camp Farm effluents that came from new land. But the point referred to in my last letter was a very interesting one, because it apparently brought out the fact that the fermentability was due not to the amount of nitrogenous matter present, but to the ratio between it and the nitrate; that, if you had excess of nitrate, then you did not ferment your organic matter. And there were some other points. The conclusion I came to was that it would be well——

5886. (*Sir Michael Foster.*) Do you think the organic nitrogen was quite in the same condition?—That is another point. It may have been reduced to the almost unfermentable organic nitrogenous matter; it is possible.

5887. Which could be indicated in the same way by the concomitants of the nitrates, I suppose?—I do not follow.

5888. Why, that when you get a large amount of nitrate in your effluent, seeing the bacterial change which has taken place in the land or whatever it is, it is possible, if not probable, that concomitantly with that there would be this change in your organic matter, which would be its unfermentable condition?—Certainly, that is another point.

5889. (*Mr. Power.*) The suggestion is that the putrefactive bacteria affected the organic matter as a whole to a much greater extent than they did the "organic" nitrogen?—Yes, possibly.

5890. Did you try to make that putrefy by the addition of other bacteria?—No, just the bacteria that were in the effluent itself.

5891. That were left in the effluent?—That were left in the effluent, yes.

5892. As to whether the organic nitrogen was capable of being further acted on, if you could put something into it beyond that which would ordinarily act upon it, you cannot say, as you have not tried that?—I have tried with a Ducat effluent, putting a solution of pure sugar into it, and in that way one got putrefaction. I took a Ducat effluent, which would keep for a perfectly indefinite length of time, and took also a solution of pure sugar, and mixed them together. The sugar was in sufficient quantity to use up the nitrate of the Ducat effluent, and next day the whole liquid was smelling badly.

5893. (*Sir Michael Foster.*) Mr. Power's point was this: Supposing you added to this effluent, which contained with the nitrates a large quantity of organic matter and did not ferment, if you added to that a culture of putrescible or putrefying organisms, whether you would have putrefaction in small amount?—No, certainly not.

5894. Did you try?—We have tried incubation experiments with these very effluents.*

5895. And the result has been?—The result has been that we did not get putrefaction.

5896. Indicating that it is the non-fermentable character of the organic nitrogen and not the absence of putrefying organisms?—No, it indicates that you have a sufficient amount of nitrate to oxidise the organic matter present.

5897. This organic nitrogen has not yet been oxidised?—It has not yet been oxidised.

5898. And would under ordinary circumstances be capable of putrefaction?—Yes, I should say so.

5899. But in this case, does not putrefy?—No.

5900. And the reason why it does not putrefy is some change in the composition of the nitrogenous body, since on adding a putrefying organism you find it does not putrefy?—You do not have putrefaction going on in the liquid so long as you have either excess of dissolved oxygen or of dissolved nitrate in that liquid. The putrefaction is indicated by a putrefactive smell, which only begins when you have used up your oxygen and nitrates.

5901. (*Mr. Power.*) The oxygen and nitrate would have to be consumed before you would have anything putrefactive?—Yes, that is the point.

5902-3. (*Sir Michael Foster.*) In other words, it would not be any test adding putrefying organisms, because putrefying organisms could not work under those conditions on account of the presence of the nitrates?—I suppose they would work. (*Dr. Houston.*) They work in a different way. I think Dr. McGowan is quite right; in the presence of nitrates or oxygen you may get a fermentative process which is not noxious and which does not give rise to any smell, but if there are no nitrates and no dissolved oxygen, then you get a fermentation which is called putrefaction or offensive.

5904. I see?—And the same organisms may act in the two cases, but in the one case they are acting in the presence of air and of nitrates, and in the other they are working more or less anaerobically.

5905. I see it is not the absence of the organisms but the condition in which the organisms are placed?—(*Dr. McGowan.*) Precisely. (*Dr. Houston.*) Yes, but the only thing is as regards the presence of the organic nitrogen. Under those circumstances I do not think there is absolute proof that it would not putrefy when it is introduced into a stream, although it might not putrefy under laboratory conditions of experiments. (*Dr. McGowan.*) If it were run into a fairly good stream it would oxidise. (*Dr. Houston.*) I do not think it would putrefy, myself, but I do not think we have proof.

5906. Because I suppose the amount of nitrate you have got present in the effluent, and which kept the organisms from developing putrefaction in the effluent, would not be sufficient necessarily to keep those organisms from developing putrefaction when the effluent was thrown into the stream?—(*Dr. McGowan.*) It would, I should say, unless in the stream they found more food in the shape of further organic matter, which is unlikely in a decent stream.

5907. So that whether that effluent could be discharged into the stream or not would depend upon the character of the stream—could be discharged without fear of putrefaction?—That is rather a wide question; I should prefer to stick to the effluent itself, to take the effluent by itself and the stream by itself.

5908. (*Professor Ramsay.*) But is this not the question: you have got an effluent containing a good amount of nitrate, which would putrefy if the nitrate were not present, turned into a stream in which there are no nitrates. These nitrates in the effluent are not sufficient to furnish oxygen for both?—It depends on the quantity; you are always getting oxygen from the air.

5909. That is what I meant—that you would have to judge from the character of the stream into which it was discharged before you could say that this was an effluent that would not give rise to putrefaction?—Yes.

5910. (*Mr. Power.*) Did you as a matter of fact get an effluent that showed little nitrate and much organic nitrogen, and yet nevertheless did not form gas bubbles under Dr. Houston's method?—Not as far as my memory goes, no.

5911. In considerable amount?—There were one or two contradictory cases, but as far as I recollect there was none like that; I would not like to be quite certain.

5912. (*Sir Michael Foster.*) Have you any reason to think that the organic nitrogen is simply the question of the nitrates and the oxygen in the presence of putrefaction?—The only reason, I think, is that you get a sort of irreducible minimum something like humus—to draw that analogy. You get a certain amount of organic matter in an effluent which does not putrefy, and it looks as if it were something analogous to humus. I have no definite grounds on which I can state this absolutely; I do not know what the organic matter is.

5913. (*Mr. Power.*) And you suspect under ordinary conditions that it has not undergone any further change?—A slow change, a very slow change; it ultimately oxidises very slowly.

5914. But very slowly?—But very slowly.

5915. (*Professor Ramsay.*) There is one more question

* But without adding extraneous organisms.—G.M.

Dr. Houston and Dr. McGowan. 13 Nov. 1900.

I should like to put to Dr. Houston; would this plan of estimating the amount of putrescibility in a test tube be quite easily applied by any unskilled person after half an hour's instruction?—(*Dr. Houston.*) Oh, yes, quite easily.

5916. (*Mr. Powvr.*) Would you leave him to measure his dilutions himself?—That would be a difficulty; but you see where I have drawn my line as a provisional standard, a positive result would be permissible in one c.c. but not in a tenth. Well, you can get pipettes graduated from one c.c. to one-tenth of a c.c. So no dilutions would be necessary.

5917. You would not trust them to deal with thousandths?—In that case the effluent would be so bad as to give in less than 24 hours a positive result with one-tenth c.c. and so would be above my standard.

5918. (*Sir Michael Foster.*) Can you supply a curve corresponding to that of the chemical result?—(*Dr. McGowan.*) Yes.

5919. It would be as well?—Do you mean the general chemical results, because we have rather elaborate analyses, or do you mean the results, say, of the chemical incubation test. What do you wish?

5920. What I want is something which was distinctly chemical?—(*Dr. Houston.*) I venture to suggest that one or two tests would suffice, say the amount of organic nitrogenous matter and the incubator gas test, the two together I should think would give all the information which was required to draw a parallel curve.

5921. Or the relation between?—Of course that would give more trouble; but it would be more valuable. (*Dr. McGowan.*) There is no ratio whatever in sewages; I think there is a certain amount of ratio when you come to the better effluents. (*Dr. Houston.*) As regards Scudder's chemical incubator test, that is rather a disadvantage, is if not, that it does not give a range of results? You say it passes or it does not pass; you do not say it does not pass by ten or more times.

5922. (*Professor Ramsay.*) Oh, quite?—That is a disadvantage.

5923. (*Mr. Power.*) At the sewage disposal works the workmen at the end of the 24 hours would just have to see whether there were gas bubbles or no gas bubbles?—That would be all.

5924. That is all he has to say?—Yes.

5925. (*Sir Michael Foster.*) Would you really want two curves, one organic nitrogen, the other nitrates?—(*Dr. McGowan.*) I should say one for the organic nitrogen and one for the results as given by the incubator test that we follow in the laboratory, and one for the general chemical results, taking the results all over; I could give you all three if you wish.

5926. That would make it too complicated, would it not?

5927. (*Mr. Power.*) To put them all into one curve, do you mean?—No, separate curves.

5928. That would not give a chemical curve?—If you leave it to me to think it over I daresay I can manage it.

5929. Is it feasible to get a curve which would represent the gross result of the chemical tests?—Yes, approximately, it would.

Mr. Frank Scudder, recalled; and further Examined.

Mr. F. Scudder.

5930. (*Professor Ramsay.*) Would you mind explaining to us what your standards are; you have the albuminoid ammonia standard and the oxygen-absorbed standard?—Yes.

5931. It would be advisable to report them from your own lips, what they are?—With regard to the limits of impurity allowable in sewage effluents, the albuminoid ammonia limit is 0·1 grain ammonia per gallon, the three minutes' permanganate test is 0·25 grain oxygen absorbed per gallon, and the four hours' permanganate test is 1·0 grain oxygen absorbed per gallon. The permanganate test is done at or about 60deg. Fahr.

5932. May I ask you do you use permanganate of any given strength?—Yes, sir.

5933. Is that specified, too?—Yes, sir. I think it is a very important matter when fixing standards that you should also describe exactly how the tests are to be carried out, and I have written out a statement here of how I do it for your information.

5934. Perhaps you will give it to the reporter?—Certainly.

Testing Sewage Effluents by the Permanganate test, four hours oxygen absorbed.

The standard solutions employed are:—

1. Permanganate of potash, 0·395 gram per litre.

2. Sulphuric acid. One part of strong acid diluted with three parts water. Permanganate of potash solution is added to the diluted acid when cold, to oxidise any compounds which would otherwise interfere with the sample to be analysed. Only a very small amount of permanganate is required; it is added until a faint but permanent pink tinge is given to the acid.

3. Sodium hyposulphite, 5·0 grams per litre.

4. Iodide of potassium, 10 per cent. solution.

5. Starch solution, prepared from "Tous le mois" starch. As much as will cover a shilling is boiled for a few minutes with a litre of water, cooled, allowed to settle, and the clear liquid decanted for use.

Method of carrying out the process.

Into a 6 oz. stoppered bottle are placed in the following order: 10 c.c. sulphuric acid, 50 c.c. permanganate of potash solution, and 70 c.c. of the sample under examination. At the same time a blank experiment is made with distilled water. After standing four hours at the laboratory temperature, potassium iodide solution is added in excess to prevent any loss of iodine, and the liberated iodine is titrated with the hyposulphite of soda solution, the end reaction being finished with the starch solution.

The three minutes' test is carried out in the same manner.

It is necessary that at least 30 per cent. of the permanganate solution should remain unconsumed after standing the requisite time, either three minutes or four hours.

For instance:

1. 50 c.c. $KMnO_4$ solution
   10 c.c. Acid
   70 c.c. Effluent
   is applicable to sewage effluents having an oxygen-absorbed test up to 2·5 grains per gallon.

2. 100 c.c. $KMnO_4$ solution
   20 c.c. Acid
   70 c.c. Effluent
   is applicable to sewage effluents having an oxygen-absorbed test up to 5·0 grains per gallon.

In Case 1 you present oxygen in the form of $KMnO_4$ to the effluent at the rate of 5 grains per gallon, and in Case 2 at the rate of 10 grains per gallon.

Example of an Analysis of a Sewage Effluent.

1. 50 c.c, $KMnO_4$ solution
   10 c.c. Acid
   70 c.c. Distilled water
   } After standing 4 hrs. required 28·8 c.c. $Na_2S_2O_3$ solution. 1 c.c, $Na_2S_2O_3$ solution = 1·736 c.c. $KMnO_4$ solution.

2. 50 c c. $KMnO_4$ solution
   10 c.c. Acid
   70 c.c. Sewage effluent
   } After standing 4 hours required 22·3 c.c. $Na_2S_2O_3$ solution.

$22·3 \times 1·736 = 38·71$ c.c. $KMnO_4$ solution
$50·0 - 38·71 = 11·29$ c.c. $KMnO_4$ consumed
$= 1·13$ grains O_2 per gallon.
or $28·8 - 22·3 \times ·003 \div 58·8 = 0·001128$ grm. O_2.
$= 1·13$ grains O_2 per gallon.

5935. How do you determine the strength of the permanganate?—With iodide of potassium and sodium hyposulphite, finishing the end reaction with starch solution.

5936. There are other ways of determining it?—Quite so. I have used the ferrous sulphate process, and, as a rule, the results are identical, but the hyposulphite process is an elegant one and, as a chemist, I prefer it.

5937. So it is an empirical test, or how did you come at it?—Well, I have been using the permanganate test for the last twenty-five years. My late master, Dr. Angus Smith, relied a great deal upon it. He said, "Nothing ever pretends to do in water analysis what the permanganate test does. Those who neglect it leave out the putrid matter, or drive it off in boiling." It is after many years of experience that I have adopted the test.

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5938. That particular way of doing it?—Yes. that particular way of doing it, and I have not altered that particular way of doing it for the last ten years; therefore, all the results I have obtained during that period are comparable. Then, I would like to explain what this dissolved oxygen test is, given on tables "A" and "B." I take one part of the sewage effluent under examination and dilute it with nine parts of tap water, shake it up to aerate it, allow it to stand two hours, and then estimate the actual amount of dissolved oxygen present.

5939. By Thresh's method?—No, by Schützenberger's method, as modified by Roscoe. The diluted samples are placed in tight-fitting stoppered bottles, the bottles are placed in an incubator, and kept at 75degs. Fahrenheit for twenty-four hours and forty-eight hours. At the end of twenty-four hours the dissolved oxygen is again determined, and also at the end of forty-eight hours. In that way we determine the rate of absorption of dissolved oxygen.

5940. During the incubation?—Yes. In other words, what I have aimed at is this:—To estimate how much dissolved oxygen a sewage effluent is capable of absorbing during periods of twenty-four hours and forty-eight hours respectively, under the most favourable conditions. One litre of the sewage effluent diluted (100 c.c. effluent + 900 c.c. tap water), will, as a rule, contain 7 c.c.'s of dissolved oxygen before incubation. That is equivalent to presenting to the original sewage effluent 7 grains of dissolved oxygen per gallon of effluent or 70 c.c.'s per litre. It is essentially a biological test. In the permanganate test we present to a sewage effluent 5 grains of oxygen, in the form of permanganate, per gallon of effluent, and that is a purely chemical test.

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5941. You see how much it consumes of those seven grains in twenty-four and forty-eight hours?—Yes. First the dissolved oxygen is determined at start, second after twenty-four hours, and third after forty-eight hours; the total volume consumed being stated in the fourth column of tables "A" and "B."

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5942. How do the two tests tally, the dissolved oxygen and the permanganate test?—They tally very well. Tables "A" and "B" have been prepared with a view of showing that. I shall come to that later on when I come to discuss standards more closely. I should, however, like to say here that the test is an important one, and whilst there exists much difference of opinion amongst chemists as to how this test of dissolved oxygen should be carried out, and be reported upon, I felt that it was much better to look at it from a purely scientific point of view as a chemist, and content myself by indicating the actual amount of dissolved oxygen absorbed by a sewage effluent under standard conditions. That is a safe ground, I think, to take. On the other hand, it is very unsafe to lay down conditions such as consideration of the volume of the sewage effluent to that of the stream into which it flows, the surface area of liquid to be exposed to the air, the power of the effluent to absorb oxygen direct from the air, the action of wind and climatic conditions, etc.; conditions in nature which are ever varying.

5943. Let me just interpret your figures into parts per hundred thousand, one grain albuminoid ammonia corresponds to 1·12 nitrogen per hundred thousand?—As nitrogen 1·176.

5944. And oxygen absorbed, 0·25 grain per gallon, corresponds to 0·25 multiplied by 10 divided by 7, equals 0·36 parts oxygen per hundred thousand?—Yes.

5945. That is 7 is to 10?—That is 0·36.

5946. And then one grain, 4 hours' test, would correspond to 1·43 per hundred thousand?—1·43 per hundred thousand. Yes.

5947. May we take it then that this standard arose from your action as regards the Mersey and Irwell Board?—Yes.

5948. You introduced it?—I introduced it.

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5949. Under Dr. Angus Smith and Sir Henry Roscoe later on?—Yes, I had already formulated these standards, and discussed them with Sir Henry Roscoe before we undertook to do this work for the Mersey and Irwell Joint Committee, but in order that the public might be satisfied, and to lead the sanitary authorities, we fixed these standards after having carried out a long series of analyses of sewage effluents derived from sewage works in the Mersey and Irwell Watershed.

5950. Have you made any experiments to show whether the albuminoid nitrogen has any relation to the total organic nitrogen in the effluent?—Yes, and it has no relation. I have made some hundreds of experiments, but I have had to discard the idea.

5951. Any idea that the total albuminoid ammonia gives you any idea of the total organic nitrogen?—Yes, for sewage effluents.

5952. Do you follow Wanklyn's ordinary process in determining albuminoid ammonia or have you any special modification?—No, I think I follow Wanklyn's process. Here again you have to be very careful; you have to lay down a systematic procedure in the laboratory. You must fix a definite volume of the sewage effluent to be taken for the determination, having regard to its organic impurity. You must also be careful that you distil over the same volume.

5953. Each time?—For instance, if you have an albuminoid ammonia of 0·434 grains to the gallon, you distil over 100 c.c. straight away; the next 50 c.c. will also contain ammonia, and the next 50 c.c. also. I therefore nesslerise the three 50 c.c.'s separately, and add the ammonia yielded to that found in the first 100 c.c. of distillate. I attach a great deal of importance to the rate at which the albuminoid ammonia is formed. It is not shown on the report, but the laboratory note-books contain these important figures. Sometimes disputes arise with regard to the albuminoid figure, but I find that it is invariably traced to the volume of distillate taken over, —some effluents persisting in yielding ammonia.

5954. Always give ammonia?—Always give ammonia. In the Mersey and Irwell Watershed I have arranged with the chemists to estimate the ammonia in not less than 250 c.c. of the distillate. I have written out a detailed statement of how I carry the test out, and hand same in.

Estimation of Albuminoid Ammonia.—Reagents required: Sodium carbonate (normal strength), 1 c.c. used for each determination.

Alkaline permanganate, 8 grms. $KMnO_4$ and 200 grms. caustic potash dissolved and made up to one litre with distilled water.

50 c.c. of alkaline permanganate are used for each determination. To 50 c.c. are added 50 c.c. distilled water, and boiled in a nickel basin down to 50 c.c. to expel any ammonia before use.

Standard ammonium chloride, 3·15 grms. of pure resublimed NH_4Cl per litre. 1 c.c. = 1 mgrm. NH_3. From this solution a weaker standard is prepared, 10 c.c. made up to 1 litre; 1 c.c. = 0·01 mgrm. NH_3, which is used as the standard for nesslerising.

Method of Procedure.—The distillation is conducted in a Bohemian round bottomed flask holding 1100 c.c. The condenser tube is made of block tin placed in a copper box, through which a stream of water passes, so as to ensure the distillates being of a constant temperature, which is a most important point in nesslerising; 700 c.c. of pure distilled water are placed in the flask, 1 c.c. Na_2CO_3 solution added, and 50 c.c. distilled over and tested for ammonia. If not quite free, a second 50 c.c. is distilled (this second 50 is invariably free). The flask is allowed to cool, and a measured quantity of the sewage effluent is added, varying from 10 c.c. to 70 c.c., according to whether the effluent is crude sewage, tank effluent, or filtered effluent. Distillation is proceeded with, 250 c.c. being distilled straight away into a 250 c.c. flask for free and saline ammonia; 50 c.c. are next distilled into a Nessler tube, and tested for ammonia, but almost invariably it will be found free. After the free and saline ammonia have been distilled off, 50 c.c. of the alkaline permanganate (previously boiled) is added, and the distillation continued, the distillate being collected in a 100 c.c. flask, then in 50 c.c. Nessler tubes, until 250 c.c. of distillate have been collected. The distillates are then nesslerised in the usual way. For instance:

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A BAD EFFLUENT. 25 c.c. taken for determination.

1. Free and Saline Ammonia.

Distillate 250 c.c. = 52·5 c.c. NH_4Cl.
10 c.c. = 2·1
next 50 c.c. = 0·0
52·5

As 25 c.c. : 70 c.c. :: 52·5 : x
x = 147·0 c.c. NH_4Cl.
= 1·47 grains per gallon.

A FAIR EFFLUENT. 50 c.c. taken for determination.

1 Free and Saline Ammonia.

Distillate 250 c.c. = 70·00 c.c. NH_4Cl.
10 = 2·8
next 50 c.c. = 0·0
70·0 c.c. NH_4Cl.

As 50 c.c. : 70 c.c. :: 70 : x
x = 98 c.c. NH_4Cl.
= 0·98 grain per gallon.

2. Albuminoid Ammonia.

100 c.c. distillate = 9·4 c.c. NH_4Cl.
50 c.c. = 4·7 ,,
next 50 c.c. = 2·8 ,,
,, 50 c.c. = 1·8 ,,
,, 50 c.c. = 1·5 ,,
(next 50 c.c. 15·5 ,,
= 1·1 not included.)

As 25 c.c. : 70 c.c. :: 15·5 : x
x = 43·4 c.c. NH_4Cl.
= 0·434 grain per gallon

2. Albumonid Ammonia.

100 c.c. Distillate = 4·8 c.c. NH_4Cl
50 = 2·4
Next 50 c.c. = 1·1 c.c. ,,
,, 50 c.c. = 0·6 c.c. ,,
50 c.c. = 0·0 c.c. ,,
6·5 c.c.

As 50 c.c. : 70 c.c. :: 6·5 : x
x = 9·1 c.c. NH_4Cl.
= 0·091 grain per gallon.

5955. Do you know whether the permanganate test as regards the effluent acts on some particular part of the organic matter; have you any idea what it does?—Well, it seems to have a selective action—that is, it seems immediately to attack and destroy the organic matter which is of a putrescible character. That is, if you have an effluent which absorbs a large volume of oxygen from permanganate of potash, it will also absorb a large volume of disolved oxygen from aerated water. The purely chemical test runs parallel with the biological test.

5956. Quite so, and for that reason you believe in the permanganate process as giving a fair indication?—I do, and I put these tables of results forward as substantiating that position. So far as I am aware, there have only been two objections raised to the permanganate process as applied to the examination of sewage effluents. The first one is that the presence of nitrites disturb the test. Well, nitrites can readily be quantitatively determined and allowed for. The other objection is that the permanganate test measures sulphuretted hydrogen. But sulphuretted hydrogen is a product of animal and vegetable decomposition, and must be taken into account. Effluents after undergoing the incubator test for five days often contain sulphuretted hydrogen, and it is an important substance to estimate.

5957. Do you not allow for the presence of ferrous iron?—It would affect the permanganate test, but I have shown elsewhere that sewage effluents do not contain sufficient ferrous iron to affect the test.

5958. So little as a rule in ordinary effluents?—So little as a rule in ordinary effluents, and also in tank effluents that have been precipitated by a ferrous salt of iron, that no allowance is necessary.

5959. Have you any reason for selecting the 60 degrees Fahrenheit, or is that only taken as a convenient temperature?—I only adopted that temperature for convenience and for practical reasons. In sending assistant chemists round to sewage works to carry out determinations on the spot, it is as well to carry out the tests under the ordinary conditions of temperature.

5960. Supposing it is summer, and the temperature is at 80 degrees, what do you do?—I make the test at 80 degrees.

5961. You do not trouble about that?—No, I do not trouble about that. I know there are chemists who only carry out the test at 80 degrees, and I have on several occasions examined how they do it, and in some instances this condition is by no means fulfilled, so I have come to the conclusion that the game is not worth the candle.

5962. In your opinion it does not very much matter within 20 or 30 degrees Fahrenheit what the temperature of the lower test is?—No.

5963. Have you tried any comparative results to see; have you found any difference?—Yes, there is a slight difference. I handed in a table last time I was here. Sir Henry Roscoe handed one in which I had prepared, showing the results obtained at 60 and 80 degrees.

5964. And they do not substantially differ?—No.

5965. To change the subject, when you are applying those tests to an effluent, do you take the whole effluent or leave out the solids?—I take the whole of the effluent, because it is in that condition as it is discharged into the river. Of course, for my own private information, and more especially with effluents containing decided amounts of suspended matter, I sometimes analyse both the sample as received and after filtering, and it throws very often considerable light on the interpretation of the analyses. Whilst I am on this subject I may perhaps be allowed to refer by way of illustration to the results obtained with effluents from the Whittaker and Bryant filter. Doubtless you have already had it in evidence that the effluent after treatment contains solid matter in suspension. The amount of total solid matter in suspension varies from 2·9 to 5·3 grains per gallon. The permanganate 4 hours' test varies from 0·98 to 1·30 grains per gallon. The albuminoid ammonia varies from 0·144 to 0·201 grains ammonia per gallon. The standards are exceeded. If, however, you remove the solids in suspension by sedimentation or filtration, and then analyse the liquid, you will find that it then complies with the standards. The albuminoid ammonia drops down to considerably below 0·1. I have a table here.

5966. Albuminoid ammonia is always in the sediment?—Yes, it is in the sediment. It is important to ascertain in cases of this description why the standards are infringed, because the effluent was found incapable of absorbing dissolved oxygen, and contained nitrogen as nitrates. By filtering or removing by sedimentation the solid matter you ascertain that, and for that reason it is necessary in practice to deal with the suspended matter from the Whittaker and Bryant filter before allowing the effluent to escape into the river.

5967. You will not actually regulate the course of your analyses by the particular matter in the effluent?—Certainly; for instance, although the results were satisfactory in many respects, I condemned the effluent, and said it ought to be filtered prior to going into the river. When that was undertaken, and the solid matter removed, then the effluent complied in every particular with those standards.

5968. (*Sir Michael Foster.*) In the Whittaker, what is the ratio between the two as regards albuminoid ammonia in suspension and in solution? You say it makes a great difference. Roughly, what is the difference between the two?—The albuminoid ammonia in the original sample was 0·144 grains per gallon. After settlement it was 0·068.

5969. (*Professor Ramsay.*) Less than half?—Less than half. The effluents are not liable to secondary decomposition, but they contain suspended matter which ought to be removed prior to entering the stream.

5970. Have you any other records of the same kind? Is it possible to draw any conclusion as to the amount of albuminoid ammonia obtainable from the sediment and from the filtered liquid?—Yes, for instance, in storm water sewage the yield of albuminoid ammonia is in a great measure due to the solids in suspension. If you pass storm water sewage through filter paper, you will find very little albuminoid ammonia yielded by the filtrate. There are other records, for instance, cases where sewage works are in operation where the bulk of the filtered effluent is good, but there are at times leakages of raw sewage into it; you will find in such cases that the sedimentary matter is most important; it sends up the results so as to condemn the effluent, although only a very minute proportion of untreated sewage may be there. For these reasons I always insist upon analysing the sample in the condition in which it is discharged into the river. To test only

for the soluble albuminoid would not help you to stop pollution.

5971. Do you bring this into your standard at all, this particular fact of the albuminoid ammonia residing largely in the filtrate or largely in the turbidity?—No, I say if a liquid does not contain more than 0·1 grain albuminoid ammonia per gallon, it can pass.

5972. Taking it overhead?—Yes, I do not take any notice in this test of the suspended matter, because you cannot get an effluent to comply with the standard if it contains suspended matter of an organic character. As a rule the bulk of the suspended matter in good effluents consists of inorganic matter, chiefly oxide of iron. The best effluents I have submitted to me for analysis are after treatment by land, and these carry the largest amount of suspended matter; they contain more than in effluents after bacterial treatment by artificial filtering media, but, as I have said, the suspended matter is chiefly oxide or iron, with very little organic matter.

5973. Yes, that is so, you must differentiate between one case and another; to effluent from land you apply one mode of treatment, and to effluent from the Whittaker filter you apply another mode of treatment. The Whittaker effluent would not agree with the Mersey and Irwell standard unless it was filtered?—Or allowed to subside.

5974. Or allowed to subside?—We should not allow the Whittaker effluent to go into the river until the suspended matter was removed.

5975. Then it would comply with your standard?—It would comply with our standard; we should object to the effluent containing suspended matter on another ground, viz., that it would cause sedimentation in the river bed.

5976. (*Sir Michael Foster.*) In the Whittaker effluent, what is roughly the proportion in the suspended matter of the organic to inorganic material, do you know?—First experiment, 1·9 mineral, 2·8 organic; second experiment, 1·8 mineral, 3·6 organic; third experiment, 1·4 mineral, 3·9 organic; fourth experiment, 2·3 mineral, 1·3 organic; fifth experiment, 1·1 mineral, 1·3 organic; and sixth experiment, 1·7 mineral, 2·4 organic.

5977. Generally more than half?—Generally more than half.

5978. (*Professor Ramsay.*) Have you any standard or particulars as to the relative amounts of suspended solids in an effluent which should be allowed to run into the river?—From a sewage effluent?

5979. Yes?—Well, I should limit the amount of suspended matter from sewage effluents to a maximum of three grains to the gallon.

5980. Is that an official limitation or your own opinion?—Well, that is the result I have arrived at from a large number of samples that have been examined. I have observed that land effluents contain more suspended matter than those from other filtering media, but the suspended matter does not exceed, as a rule, the maximum of three grains to the gallon.

5981. If it does you reject it?—If it does we reject it; if above the three grains, then the albuminoid ammonia test would condemn it.

5982. Without the trouble of estimating the suspended matter?—Yes, without that trouble. Of course, when you come to bacterially treated effluents, if the beds are worked properly, then you have effluents practically free from suspended matter, only cloudiness.

5983. Then let me take it, to sum up this part of it, that you do not determine the oxygen absorbed in the clear effluent, you determine oxygen absorbed in the total effluent?—I determine oxygen absorbed in the total effluent. When I was before you last time I put in some tables of analyses showing the difference between the oxygen absorbed on the samples shaken before analysis, and the clear liquid after settlement; the results were very instructive; a long series of experiments.

5984. Then do you think a good part of the oxygen absorbed goes to oxidise the suspended matter?—No, I do not think so; I think the bulk of it goes to the soluble, because there is very little suspended organic matter there to be oxidised.

5985. In the suspended matter surely there must be; suspended matter consists a good deal of organic matter?—I was thinking of good effluents that ought not to have more than three grains of solids per gallon. Of course, the organic matter of the suspended solids is ravenously attacked by permanganate.

5986. But I mean the free oxygen absorbed also goes to oxidise the solid matter, does it not, in your incubator test?—Yes, but it prefers the soluble, it attacks the soluble in preference to the insoluble.

5987. But with the incubator test you deal with the whole effluent?—I deal with the whole effluent, certainly.

5988. Would you mind describing the incubator test, to have it on record?—The incubator test I introduced, I think, about 1895, to serve the following purpose:—There was a feeling amongst chemists on the Mersey and Irwell Watershed that the Conservancy Board ought to be satisfied with a chemically treated effluent, and it was necessary to point out that even after chemical treatment the effluent was liable to secondary decomposition—that it was liable to smell; and in order that I might guide gentlemen who were not chemists in this matter to appreciate the value of filtration as an essential process of purification, I brought out this incubator test, and shortly described it is as follows:—You take a glass-stoppered bottle full of the effluent, and expose it in the incubator to a temperature of 75 degrees Fahrenheit for from three to five days. No instance has come under my observation where a chemically-treated tank effluent did not produce a smell under these conditions. On the other hand, with good effluents they remain sweet during the period of incubation. It was a test that you give the non-scientific man to carry out on a mantelpiece by his own fireside. Indeed, in the case of Manchester I distributed the tank effluent in stoppered bottles to members of the Rivers Committee, and asked them to keep it for two or three days. They very soon found out that the effluent underwent putrefaction. It was a simple test readily taken up by the sanitary authorities, and used by the Manchester Corporation themselves, because when they came to deal with the tank effluent by filtration they found out that the effluent was no longer liable to putrefaction, and that the test was a valuable guide. I want, however, to guard myself against the incubator test. It has been rather overused, and like all other tests it will not stand too much.

5989. It is an educational more than a scientific one?—Quite so. Now, I think, it can be brought forward as a scientific test.

5990. After you have done this, you test the oxygen absorbed from permanganate again, do you?—Yes, I apply the three minutes test. Although I also apply the four hours test, yet I have not been able to get any value from it, but with the three minutes test I obtain valuable figures, which can with advantage be shown in diagrammatic form, of the amount of the putrescence produced. When, however, sanitary authorities took up the question of filtration seriously, I observed that in some cases effluents that would not comply with the standards did comply with the incubator test. It was observed that an effluent containing nitrates, when placed in the incubator, did not produce an offensive smell, and that the three minutes permanganate test did not give a higher result, although all the standards were infringed. It was, therefore, necessary to examine by more scientific methods the changes that effluents undergo during incubation, and for that purpose I adopted two methods. The first was to measure the rate at which dissolved oxygen was absorbed, and the second to measure the rate at which nitrates disappeared from the effluent during the period of incubation. My point is this, that if you have an effluent which is capable of robbing aerated water of its dissolved oxygen, and has also the power of destroying nitrates, it is going to bring about a condition which is evil or liable to be evil, and that is my definition of a polluting effluent.

5991. Is it necessary to determine the nitrates at the same time?—Very important.

5992. Do you systematically determine the nitrates?—Certainly, I do.

5993. Would you modify your general Mersey and Irwell standard by introducing some statement about the amount of nitrates in the water. Do you or do you not consider it necessary to do that?—Yes, I consider it very important to take into consideration the rate at which nitrates disappear. I have for some time been thinking this matter over, and from the information now acquired, I am inclined to define a non-polluting sewage effluent as an effluent capable of absorbing from

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an acid solution of permanganate of potash, acting at 60 degrees Fahrenheit, not more than 0·5 grain of oxygen per gallon of effluent.

5994. (*Colonel Harding.*) That is half the Mersey and Irwell standard?—That is half the Mersey and Irwell standard. With the three minutes test the effluent should not exceed a quarter of a grain oxygen absorbed, and with the albuminoid ammonia test the ammonia should not exceed 0·1 of a grain. Moreover the effluent ought to be incapable of absorbing more than two grains of dissolved oxygen per gallon of effluent from aerated water (1 volume effluent mixed with 9 volumes of tap water), at a temperature of 75 degrees Fahrenheit acting for 48 hours; and the effluent ought not to appreciably destroy nitrates when these are added to it, during a period of incubation for 48 hours at 75 degrees Fahrenheit.

5995. (*Professor Ramsay.*) Then you estimate the nitrates before and afterwards?—I add to the sewage effluent a definite amount of nitrate of potash, equivalent to 0·25 grain nitrogen as nitrate per gallon of effluent, and I determine the rate at which the nitrate disappears.

5996. That means two estimations of nitrates, one before and one after?—Three, one at the commencement, one after 24 hours, and one after 48 hours.

5997. Estimating the nitrates before and after at each stage?—**Yes.**

5998. Have you any special means of estimating the nitrates?—I have a special method for determining nitrites and nitrates together.

5999. May I ask what it is?—Yes, I measure 70 c.c. of the sewage effluent into a nickel basin, add 0·5 c.c. normal Na_2CO_3, evaporate to dryness on a water bath to get rid of ammonia, redissolve in distilled water, transfer the liquid to a glass preparation tube 6 inches long by 1½ inches wide, with a 50 c.c. mark, and make the liquid up to 50 c.c. with distilled water. I then add 5 c.c. of a 25 per cent. pure hydrochloric acid (recently distilled from H_2SO_4, and NH_3—free), and then a piece of thin aluminium sheet weighing from 0·5 to 0·7 gram, and measuring about 2 inches by 1 inch, which has been amalgamated by either dipping into $HgCl_2$ solution, or preferably by standing 20 minutes in Nessler residues. A vigorous action at once commences, and to prevent loss of escaping vapour a cork fitted with protection tube, filled with glass wool and moistened with water, is attached to the preparation tube. No NH_3 can escape, as it is held by the acid solution. In this manner 1 grain nitrogen as nitrates per gallon can easily be reduced to ammonia in one hour. After reduction, the acid solution is added to an alkaline liquid in a flask which has been distilled free from ammonia, and distilled. The ammonia is then estimated in the distillate.

6000. Have you tried it without distilling?—Yes, I have tried it without distilling, but I prefer to distil over and nesslerise the distillate, because, in many cases, the colour of the nessler is affected, and accurate results cannot be obtained with sewage effluents by direct nesslerisation. I have done this really scientifically, in order to get accurate results. All the different methods of reduction described in the text books on water analysis are not to be relied upon. You must have a definite relation of the volume of the effluent to the surface area of the amalgamated aluminium foil.

6001. Have you formed any theory as to how the nitrates disappear by any action of bacteria?—Yes, I think it is pretty conclusive that nitrogen gas is evolved from the nitrate.

6002. The whole of the nitrogen is removed?—The whole of the nitrogen is removed. I might, whilst on this point, refer to a report by the late Dr. Angus Smith. I made the experiments for him upon this matter. I am quoting from a report to the Local Government Board by Dr. Smith, who was inspector under the Rivers Pollution Prevention Act, 1876, dated 1884. That was the year of Dr. Angus Smith's death. On page 23 he gives some additional results illustrating the escape of free nitrogen from sewer river water, when nitre is added:—

(1) Medlock water collected April 30th, 1883, 1,150 c.c. + 1 grm. KNO_3. Gas evolved 103·3 c.c. nitrogen; 1 grm. KNO_3 contains 110·2 c.c. nitrogen.

(2) Medlock water 50 c.c. + 50 milligrammes KNO_3. Gas evolved 4·8 c.c. nitrogen; 50 mgrms. KNO_3 contain 5·51 c.c. nitrogen.

(3) Bridgewater Canal water, 50 c.c. + 50 mgrms. KNO_3. No gas evolved during 46 days' observation.

(4) Manchester water containing nitrate of potash did not evolve any gas during 46 days' observation.

(5) Salford sewage 50 c.c. + 50 mgrms. KNO_3. Gas evolved 5·53 c.c; 50 mgrms. KNO_3 contain 5·51 c.c. nitrogen.

(6) Salford sewage 350 c.c. + 0·35 grm. KNO_3. Gas evolved 37·8 c.c. nitrogen; 0·35 grm. KNO_3 contains 38·6 c.c. nitrogen.

These experiments made in 1883 showed that we were measuring bacterial forces by chemical means. We also added grape sugar to contaminated waters, and measured the volume of hydrogen evolved.

6003. Have you ever thought that it would be a good way of determining the putrescibility of a water simply to measure the rate at which nitrogen is evolved from nitrates?—I have some tables showing the rate at which nitrates disappear.

6004. You do that by measuring the nitrates; could it not be estimated by measuring the nitrogen?—That would involve the use of gas apparatus and great refinement of working, as the volume of nitrogen evolved is so small and so difficult to measure. If a sewage effluent contained 1·8 grains nitrate of potash per gallon, equivalent to 0·25 grain nitrogen, the volume of nitrogen evolved would be only 12·9 c.c. per gallon. I do not think it could be done.

6005. You say that you incubate from three to five days?—After three days incubation you reach a point beyond which you do not, as a general rule, obtain higher results, but the maximum smell is developed in every case after five days. Beyond five days no higher result is obtained—that is, with the three minutes' test. If you apply it at the end of five days you will get *x* result, and if you apply it at the end of a month you will only get *x* result.

6006. Does that imply two sets of experiments, one for three days and one for five days? How can you know that the whole thing is over in three days?—By its appearance; it has gone quite black, and sometimes it will burst the bottle by the gas generated.

6007. That would at once put an end to your experiment?—Yes.

6008. How do you know, do you keep it on to five days or terminate it at the end of three?—All the tests that are reported are kept in the incubator for five days. At the end of three days we go to the incubator and pick out those that are black, and after noting their appearance and smell, throw them away, but in all cases of importance, and in every case reported upon, they are kept on for five days, so that all the results are comparable.

6009. Do you find that what they call a sweet smell (not a putrescent smell) and diminution of oxygen absorbed, do they always agree in a good effluent?—Yes.

6010. You find that is invariably so?—That is so, although you get to what I have stated in my *précis* to a critical point. For instance, on reference to Tables "A" and "B," you will observe in one example where the four hours' test was 0·86 grain that that effluent went bad in the incubator. I do not think you will ever find an effluent having an oxygen absorbed below 0·7 acting in this way, but from 0·7 to 1·0 is sometimes doubtful, though they are only exceptional; as a rule, you may take it they do not.

6011. So I may take it that the albuminoid ammonia and the oxygen absorbed and the incubator test agree with each other within broad limits?—They do.

6012. And you make use of all three? In the case when you found a sample to putrefy which showed 0·86 of oxygen absorbed, was the albuminoid ammonia bad?—It was very bad—0·21 grain.

6013. And you would have condemned it for the albuminoid alone?—Yes, and the three minutes' test was 0·43, so I had two tests there, you see, out of three, that were fatal to the sample. Then I had also the incubator test, which showed the effluent to be of a putrescible character.

6014. I think in that document you give something of a percentage number of samples which do not come up to the standard, do you not?—Yes, I do.

6015. In what number of samples have your standards not justified reduction, and yet the effluent should be rejected?—I beg your pardon, I do not think I quite understand that question, sir.

6016. There are some cases in which the sample would pass your standard, and yet it would putrefy, I understand?—Yes, that is so.

6017. Do these form any large percentage of the number of cases that you report?—No, they come out about 1 in every 50.

6018. About 2 per cent.?—I tried to get it out accurately, but my assistant could not get it out nearer than about 1 in every 50.

6019. About 2 per cent.?—Yes, about 2 per cent.

6020. Have you altered your view as regards the Mersey and Irwell standard at all, or do you still maintain it is the most convenient to use for practical purposes?—I have not altered my view, and I believe it is the most convenient to use for practical purposes.

6021. Would you make it more stringent?—There is a danger in making it more stringent from the practical point of view. If the authorities realise that you are fixing a hard and a more rigid standard, they will fight against it. I believe in educating them up to it.

6022. Then you think they might?—They might. I would bring the standard down to half a grain if I could, but we cannot do that until we have got conclusive evidence on the results of filtration. For instance, in 1894 we had not very much reliable information with regard to the effect of filtration, and no practical results. Now we have practical results, and all the authorities are working carefully on the subject. I do not think at the present time you would find one dissentient in the whole of the Mersey and Irwell watershed—chemist or practical man—who would object to the one grain standard. It is because we have not sufficient evidence of the results of filtration that I am loath to bring the standard down to half a grain.

6023. The whole question is one of admissibility or not of the Mersey and Irwell standard as a means of measuring putrescibility in other towns?—That is so.

6024. Would it not be better to discard the Mersey and Irwell standard, except for convenience for your own practical use, and, say, an effluent will be allowed to pass that will not putrefy?—As I have already pointed out there may be an effluent which will not putrefy in the incubator, because it is protected by nitrates.

6025. Quite so, but will not putrefy in a stream or river water with which it is going to mix?—Supposing you had a sewage effluent having an oxygen absorbed of 1·5, and containing 0·25 grain nitrogen as nitrates. During the five days of incubation at 75 degrees that effluent does not putrefy. Well, you must not pass that, because it does not putrefy; it is a polluting liquid; it is not fit to go into the river, because that effluent is not only capable of destroying in 48 hours the whole of the nitrates originally present, but it is also at the same time capable of absorbing the whole of the dissolved oxygen in three times its volume of aerated water.

6026. Then it is after all a question of degree, of course, as to how much water it is to be mixed with?—Yes, but if you have an effluent which is capable of absorbing dissolved oxygen from several times its volume of aerated water, you must not pass that effluent as suitable for a river. That is why I say the incubator test must be tallied with the action of the disappearance of nitrates and of dissolved oxygen, and not from the question of putrescence, whether it smells or not.

6027. No, I do not think we are regarding putrescence in the same light. You mean putrescence, whether a thing will smell or not; I mean, under any circumstances whatever it will putrefy?—If you mean then by putrefaction whether the effluent is capable of removing from aerated water the dissolved oxygen and of destroying nitrates, then I agree with you.

6028. Would it not be practicable to make a test of that kind, that the effluent does not provide food for bacteria, is not putrescible in fact?—Yes, but you must define what you mean by putrefaction, because the definition of putrefaction, or secondary decomposition, as we understand it, and as we have educated people to understand it, is the production of an offensive smell.

6029. That is not the whole story; the point is, will this effluent serve for food for bacteria or not. If there is anything which will serve for food for bacteria, it will putrefy; that is my view?—If you define it in that way, you do not define putrefaction in the same way as we have defined it.

6030. Is it not possible to permit a standard which will apply to that sort of non-putrescibility?—You can do that, but that surely must be a definition of what is a non-polluting effluent.

6031. Precisely, but do you think that is too hard a thing to ask for?—Oh yes; you must educate the public to such a standard gradually. I will give you a parallel to that which is in my mind. The Cotton Cloth Factories Acts 1889 and 1897 deal with the ventilation in cotton weaving sheds, and Sir Henry Roscoe's Committee, who had to investigate the matter, fixed a standard for the maximum amount of carbonic acid allowable in a weaving shed, and an order of the Secretary of State legalised that standard. They fixed a standard of 9 volumes of carbonic acid per 10,000 volumes of air, and any manufacturer who does not ventilate his shed so as to keep the amount of carbonic acid below nine is liable to a penalty. I have had some experience in prosecutions under this clause, and although we have obtained orders for the violation of the standard, we have had to fight very hard to show that is was possible to keep below nine, and the magistrates who have tried these cases in Lancashire, some of whom are interested in these mills, have said:—As there is such a clause in force, we have no alternative but to inflict a fine. They have much sympathy with the manufacturer, but there is a rigid rule to abide by, and they inflict only a nominal fine. In the same way, if you fix a standard for sewage effluents of half a grain, we shall go with cases to court, and the magistrates will say, Here is a rigid rule, we will impose a nominal fine. We want penalties to be put on that will make the authorities do their duty.

6032. I am afraid we are a little at cross purposes; my point is this, instead of defining your standards in the ordinary form of the Mersey and Irwell standards of 0·1 grain of albuminoid ammonia, and not more than 1·0 grain of oxygen absorbed, and so on, would it not be better to define a standard as an effluent which may be turned out, which when submitted to searching tests will not putrefy?—I should like this Commission to say that, but I should not like to work the Mersey and Irwell work with that standard. The authorities would say this, "You are going rather too strong in regard to your standard. You are asking us to do too much at this stage."

6033. Do you think it is an unreachable thing, now we know the circumstances?—I do not think it unreachable; it will be reached when you get authorities to carry out filtration works for sewage purification.

6034. Do you not think things are so advanced—the erection of such works—that it has ceased to be unreachable?—No, I do not think they are sufficiently advanced.

6035. Do you know any works where such an effluent is produced?—Yes.

6036. Is it not possible to cause corporations to imitate them?—That takes time; that is what they are all doing; they are improving their position.

6037. In the ordinary course of events the inspectors who look after the standards would naturally enough be lenient for some time—give them five or ten years to reach this standard, as in the case of the Alkali Acts, passed with a view to prevent so much acid fumes escaping from chimneys?—In the case of the Alkali Acts the standards were fixed at random.

6038. I know they were, but the inspectors have been lenient and not overpressed the manufacturers?—The standards are however useless.

6039. But as a matter of fact they are conformed to?—They were conformed to the first year they were passed. The Alkali Act was passed in 1863. The alkali interest took great care to have a standard fixed that would allow 5 per cent. of the acid made to escape. That was the extreme escape allowable. The Act came into force in June, 1863. In 1864 Dr. Angus Smith reported that there were 85 alkali works in the country, and that the average escape of acid gas over the whole of the kingdom was 1·28 per cent. of that produced. The Act allowed 5 per cent. The demands of the Alkali Acts are such as not to protect vegetation and to stop cases of arbitration for compensation for damage to crops.

6040. I know that?—Then in 1874 the Act was amended, but the same clause was kept in, with this addition, that the hydrochloric acid escaping in the chimney gases should not exceed 0·2 grain per cubic foot of chimney gases. In 1892 the average escape was 0·09, and in 1899 it was 0·068, or less than half the limit of the Act. In 1882 the amended Act fixed a limit of escape of 4 grains of acid compounds of sulphur and nitrogen, calculated as sulphuric anhydride, per cubic foot. In 1892

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the escape was only 1·284, in 1897 1·184, and in 1899 1·317, *i.e.*, less than one-third the limit of the Act.

6041. I know the average escape is below the limit allowable?—Those standards have not touched the damage to vegetation or the damage to health one bit.

6042. It has not improved it?—It does not improve it. No, the fixing of standards are of no use in the Alkali Acts.

6043. (*Sir Michael Foster.*) Because the standard was too low, it is so easy to meet?—The standard was so high it was so easy to keep below it. Dr. Angus Smith's idea was that the hydrochloric acid limit of 0·2 grain ought to be gradually lowered at the rate of 0·01 grain every year. In the same way with regard to a standard for sewage effluents, I should like to see the limit of 1 grain oxygen absorbed gradually lowered to the half grain standard.

6044. (*Professor Ramsay.*) But is it quite the same—are the two cases quite parallel? The moral I wanted to draw from the Alkali Acts was that the inspectors did not press too hardly on manufacturers; as a matter of fact they kept on very good terms with the manufacturers?—That is so.

6045. You know that is so?—Certainly.

6046. Supposing we were to aim at an absolutely non-putrescible liquid that will not putrefy, but not to press it too hard at first, do you not think it possible by setting a high standard and increasing the pressure gradually, in the course of ten years that standard would be reached?—Yes, but I am looking at the difficulties we have in law cases. For instance, supposing we want to obtain an order against the Manchester Corporation, and we have a standard such as you have described, expert witnesses will be brought on the other side to show that it is not obtainable, and then where are we?

6047. From your own statement you say you know cases of filtration works where it is obtained?—I know, but there is still a difficulty. You simply define what is a non-polluting effluent and leave it there. It is open to a fight in the law courts as to whether it can be accomplished or not. On the other hand, with a standard of 1 grain oxygen absorbed, which admits pollution, the authority would have to show that it is not a polluting liquid, and they cannot do that. I am looking for the ease we want in prosecuting an authority. If I say I know works where a standard of half a grain oxygen absorbed is attained, the opposition could very well argue that because that standard is attained in one place it does not necessarily follow that it can be attained in other places. Take the Polarite system at Chorley, those works comply with such a standard, but the Manchester Corporation would not listen to the Polarite system being applied to the treatment of the whole sewage of Manchester.

6048. Certainly not. I quite agree, but there are other cases where other systems are used with the best results?—Yes, but there are chemists who do not know that.

6049. They would not know; they would learn it?

(*Mr. Killick.*) It is 30 years since the last Commission reported, and the Mersey and Irwell standard has been at work 10 years, so that the progress has been very small outside. There is no progress at all except in special cases like the Thames. You cannot go faster than you will take the public with you. Speaking as a member of the Mersey and Irwell Joint Committee, I fully endorse what Mr. Scudder says. At the present time we have no sympathy from the public in bringing actions against the authorities for passing what you describe and what he describes as a putrescent effluent, at the same time we ought to aim at attaining such a standard eventually. It is perfectly hopeless at present. You have not even got the action as far as accepting the provisional standard which we have adopted.

(*Professor Ramsay.*) Yes, I see.

(*Witness.*) From my point of view as a chemist, I say the Mersey and Irwell Joint Committee have done good work; they have done excellent work in getting the public, the sanitary authorities, and the chairmen of all these sewage boards to appreciate the importance of adopting some system of filtration—of course, by filtration I mean the broad definition, including bacterial treatment. This has brought about a great deal of enthusiasm, and a large amount of money is now being expended with a view of testing this question of filtration. If the authorities eventually adopt it permanently, we shall have a fresh set of results upon which to frame a better standard.

6050. My question was only whether it had not been sufficiently adopted already?

(*Mr. Killick.*) Not within sight of it from the practical point of view; I am sure Colonel Harding will fully endorse that as a member of the West-Riding Board.

(*Witness.*) By the use of this provisional standard of 1 grain, the Mersey and Irwell Joint Committee can proceed against any authority in the watershed without any trouble, if the effluent is above the standard one. No chemist can then come forward and say it is not a polluting liquid. The chemical evidence disappears, and that is a matter of great importance to a Rivers Board. We found that out in 1895 when we commenced an action against the Salford Corporation. They put up their backs; they wanted to adopt a standard three times as high as the Royal Commissioners' standards of 1868 (*i.e.*, three times worse than those standards), which would have had the effect of allowing raw sewage into the river. That trial costs hundreds and thousands of pounds. They employed every chemist they could to oppose, but they lost the action. Now it is admitted by everyone that the standard of 1 is a good and workable limit.

6051. And you can be sure of getting a conviction?—And we can be sure of getting a conviction. We have got a conviction on 0·9, but it was a special case. If it is going to be a question for the chemists to fight, then it will make matters very complicated, and those authorities who are prosecuted will employ chemists who will oppose you. We have removed that opposition by fixing a provisional standard of 1, so that any opposition cannot stand on its legs.

6052. (*Mr. Power.*) I take it, Mr. Scudder, that you agree with Professor Ramsay that the theoretical standard should be that the liquid was non-polluting. You are only objecting to it as a provisional standard at the present time?—That is so. I am glad you have put it in that way. I would like a Commission of this importance to state that, but if we had brought forward such a proposition when we commenced this work the authorities would have made no progress, they would have said: "You are asking for something which is unreasonable, and your demands are too exacting." We must gradually educate them up to it from the incubator test carried out in a rough-and-ready way up a more exact and scientific test.

6053. (*Professor Ramsay.*) And you consider they are not quite educated yet?—They are not quite educated yet. Manchester will soon have an area of ten or twenty acres of filter beds in operation, and then will be our time to work up the standard.

6054. It is by no means at that standard now?—No. I should like them to get practical results.

6055. Do you think as long as there are nitrates present no putrefaction takes place; you must exhaust the nitrate before the putrefaction will begin?—Yes, if you take an effluent which is condemned by the oxygen absorbed and the albuminoid ammonia, and if to that effluent you add, say, half a grain of nitrogen as nitrate and nine volumes of aerated water, you will find on incubation that not only the nitrogen of the nitrate is destroyed, but you will find also that the dissolved oxygen is absorbed; they both go together.

6056. I was going to ask that, do they happen contemporaneously, or one before the other?—The dissolved oxygen disappears a little more rapidly than the nitrate, but they do disappear together. It is rather important. I have made a number of experiments bearing on that point. It has been suggested by the largest authority we have in the Watershed, viz., Manchester, that they might take, say, a million gallons of a tank effluent, and mix it with, say, five million gallons of an effluent after bacterial treatment. Such a mixture would comply with the permanganate test and the albuminoid ammonia test, but it would not comply with the incubator test carried out as I have described.

6057. No, I see——

6058. (*Sir Michael Foster.*) The effect of the bacterial addition would be the nitrates which are present; it depends upon them?—Yes. Take the case of a sewage effluent, where the oxygen absorbed was 1·42, and the albuminoid ammonia 0·266. That effluent when mixed with nine times its volume of aerated water gave an oxygen absorbed of 0·45. Before incubation it con-

tained 0·122 grain nitrogen as nitrates and 7·99 c.c. dissolved oxygen per litre. After 24 hours incubation at 75deg. Fahr. the nitrate had fallen down to 0·08, and the dissolved oxygen to 1·8 c.c. per litre. After 48 hours all the nitrate and dissolved oxygen had disappeared. Now, on the other hand, if you take an effluent that has been legitimately produced from bacterial treatment, with an oxygen absorbed of half a grain, it does not behave in that manner. For instance, an effluent having an oxygen absorbed of 0·45, when mixed with nine times its volume of aerated water, contained 6·9 c.c. dissolved oxygen per litre. After 24 hours incubation the dissolved oxygen was 6·8, and after 48 hours 5·3. The nitrogen as nitrates, 0·10 at start, fell to 0·08 after 48 hours. I have made a number of experiments on the effect of dilution, and it appears clear that if you take crude sewage and dilute it with tap water so as to comply with the chemical standards, the incubator test finding out the loss of nitrate and of dissolved oxygen is of great value in indicating pollution.

6059. (*Professor Ramsay.*) Would you not be content with the incubator test alone, without the others, the incubator test finding out how the dissolved oxygen has diminished, and how nitrates have diminished if they are there; would not that tell you all you want to know?—Leave out the dilution?

6060. No, I mean incubate and measure the amount of dissolved oxygen before and after, and the amount of nitrates before and after incubation?—Very valuable tests, if carried out as I have described.

6061. But does not that tell you all you want to know; what more do you gain from the permanganate test?—Except that you can do the permanganate test more easily; it is an easier test to carry out, and it is a chemical test.

6062. It gives you the same information?—It gives you the same information with the exception of cases where dilution takes place, but only a scientific chemist, or one having laboratory practice, could undertake to do this, the chemist having to test effluent from time to time has not time to carry out these scientific determinations. I wanted if possible to get a test so simple that even the foreman of the works could carry it out. The permanganate test fulfils that condition except in cases of dilution. I am only putting in all this information to show that as a rule these scientific tests tally with the permanganate test, and it would be a serious matter if we had to rely upon these two scientific tests, because the sanitary authorities would not carry them out; they would not check the working at all, but by the permanganate test it would get checked.

6063. Supposing an effluent, after being incubated by itself for five days, still contains nitrates, would you call it all right?—Still contains nitrates?

6064. Yes; do you think that five days is sufficient for an effluent to use up all the nitrates?—Well, it depends upon how much you presented to it.

6065. Its own nitrates, I mean?—You cannot do that, it must not have its own nitrates; its own nitrates disappear in 24 hours, if it is over half a grain to the gallon standard.

6066. You find that is so always?—Yes, if it is over half a grain to the gallon.

6067. If what is over half a grain to the gallon?—The oxygen absorbed.

6068. It will consume its own nitrates?—It will consume its own nitrates.

6069. (*Mr. Power.*) In 24 hours?—Yes, in 24 hours.

6070. (*Professor Ramsay.*) Well, I suppose we may take it as the result of this long talk that in a few cases, about two per cent., you find that samples which pass your test do putrefy?—Yes.

6071. And I suppose you would also say that a certain number of samples which do not pass your test are not putrescible; would not under any circumstances putrefy?—That is so.

6072. So that it is only a test which takes in the great average of cases, but is not invariable to every one?—Yes, that is so.

6073. Do you know if you apply your test to a drinking water, whether dissolved oxygen will decrease on incubation; has that been tried?—Yes, I have tried also experiments like that. It all depends upon what water you have to test. There are some waters that will remain stationary as regards dissolved oxygen, and some that will decrease. It depends on the bacterial contents.

6074. On the amount—the number of bacteria in the water?—Yes, there are some waters that have a great amount of bacteria or vegetable growths producing offensive smells; these will grow worse with incubation. For instance, peaty waters will improve; Manchester water will improve in the incubator. Of course that opens up a very interesting question from a scientific point of view. There was a discussion between Mr. Warington and the late Dr. Angus Smith, as to whether peat did nitrify, but, as a matter of fact, I find that Manchester water, which is a peaty water, does nitrify in the incubator. But of course all drinking water that I have come across will not destroy nitrates.

6075. (*Sir Michael Foster.*) What was the drinking water containing such a quantity of bacteria that it would putrefy? You said if it contained a sufficient number of bacteria; you were speaking of the actual samples?—I am speaking of the waters used in many parts of the country, but the names of the places are for the moment out of mind; the water was used for public baths. After the water had been thrown into the baths, and used for two or three days, vegetable growths appeared, and became troublesome—it is the baths at Cheltenham and at Bolton. The water supply I suppose is a good drinking supply, but when it is exposed in the bath the vegetable slimes increase so much that it becomes offensive. Now a water of that description will putrefy very rapidly in the incubator. I cannot speak of the particular organisms that are liable to produce these smells.

6076. (*Professor Ramsay.*) Have you had experience of the Mersey and Irwell standard with farms; do you think it can be reached with careful farm treatment?—With farms; oh, yes. On farms you can get the half grain. At the Stretford sewage farm, for example, you can never get it above half a grain. That is one of the best sewage farms, and there you never get it over the half grain to the gallon.

6077. Have you had a large experience of farms?—Yes.

6078. And do you find it common, becaues our experience is mostly the other way—condemned by your standard. I think there is only one or two which have been examined which would pass your standard at all?—It depends on where you go to to get your samples. If you take an area of land under proper treatment of sewage, there it will comply, but if you go down, say to osier beds that have not been attended to, and where the sewage flows over the surface, there you get bad effluents.

6079. That is not the question. Take it where it flows into the stream, the final effluent as far as possible?—Take Croydon sewage farm, that would comply with the half-grain standard.

(*Dr. McGowan.*) It does not do so at the present moment, but——

6080. (*Mr. Killick.*) Where does Mr. Scudder get his figures from?—I have personal experience of it. I have been all over the country, and analysed from all the sewage farms. We presented a report on the effluents from the sewage farms in England to the Local Government Board, showing that land filtration did give you a standard effluent.

6081. If the soil is perfect, and the management good, it does, but if the soil is not good, and the management not good, it will not do?—On clay soil, of course, you cannot do it; you want suitable filtering soil.

6082. (*Sir Michael Foster.*) Has this land at the Croydon farm deteriorated since you visited it?

(*Dr. McGowan.*) They are pressed for room there, and they are putting down filter beds.

6083. (*Sir Michael Foster.*) Has there been increased pressure to deteriorate it since Mr. Scudder's visit?—(*Mr. Scudder.*) At Harrogate you get an effluent almost equal to our Manchester water supply.

6084. (*Professor Ramsay.*) That is very different from our experience?—Allow me to finish. I went six months afterwards to the sewage farm, and I found that they had concentrated the whole of the sewage on a small area of land, and there the conditions were something cruel, the effluent was bad; but when they distributed and used an adequate area for the volume of sewage, then a good result was obtained.

6085. (*Mr. Killick.*) The farms in our own area—Stretford?—Are always satisfactory. I have never had a bad sample sent me from Stretford farm. They have got good

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conditions of soil to filter on; there is a large area always available, and a minimum volume of sewage applied with good management.

6086. Are there any other farms in the watershed that are always good?—No. Not that are always good. That is the value of having inspection, because you find sometimes they have concentrated the sewage on a small filtering area. Take the Wilmslow sewage farm, which is perfectly competent to turn out effluents of less than half a grain when properly attended to, but there are times when they concentrate the sewage on too small an area of land, and, therefore, at these times bad results are obtained.

6087. (*Mr. Power.*) It is a question of management altogether?—A question of management, yes. I had that in my mind when I gave you the accounts of the unsatisfactory samples, showing what the excuses were for getting these bad samples. If you go to an old sewage farm they say the unsatisfactory effluent is due to rat-holes, that the place is over-run with rats; that is merely bad management, they ought never to allow it to get into that condition to be over-run with rat-holes, it is a case of negligence.

6088. (*Professor Ramsay.*) Quite so. Well, the only other question I would ask you is as regards your views of a definite standard. Do you advocate your present standard—the continuance of it, or the application of it to the whole country for the present?—Yes, I do.

6089. With the hope of raising it at a later date?—Yes; at the same time that you fix standards I think it is very necessary that you should describe how the tests are to be carried out; for instance, in the same way as the instructions are issued for gas testing. You have to do that under certain regulations, there are certain things you have to follow, because if you do not do so those tests can be evaded by the chemists who wish to do so, and yet who are working legitimately.

6090. (*Mr. Killick.*) I should like with reference to Mr. Scudder's last answer, to ask a few questions. Professor Ramsay asked you if you would recommend your Mersey and Irwell standard for adoption for the whole of the kingdom, but those standards you yourself, or Sir Henry Roscoe, described as provisional standards?—Yes.

6091. Well, that is a great difference; the theoretical or test standard would be one that Professor Ramsay mentioned, not our Mersey and Irwell standards?—I would not advocate the rigid application of those standards; they are treated with us as provisional standards.

6092. (*Professor Ramsay.*) But provisional in this sense that you will make them more rigid as time goes on?—Exactly.

6093. As you gain experience?—Yes.

6094. (*Mr Killick.*) And you think we could ask for, or are justified in asking for that at the present time, but at the same time a higher standard might be laid down as the definition which should be reached ultimately?—Yes, quite.

6095. (*Professor Ramsay.*) Another question, are you dealing with this standard with reference to Manchester or other large towns, or do you think that a more rigid standard could be applied to country places?—I think a more rigid standard could be applied to small places,—I think, Urban District Councils. I have been speaking, having in view large towns.

6096. It was a most difficult problem?—Quite so.

6097. (*Mr. Killick.*) Then comes this practical point, if you have different standards for different authorities, you increase the difficulties of enforcing any standard eventually. They can understand equal justice for all; they cannot understand different standards being used in a different set of cases?—There is another point I should like to bring forward, why I should like the standard of oxygen absorbed to remain at 1. A sanitary authority is called upon to deal with a definite volume of sewage and of storm water sewage. The resulting effluent complies with the standard, but storm water sewage is at times passed direct into the stream, causing pollution, and we have to consider what the storm overflows carry and the effect produced from them, especially in view of these analyses, which show that dilution is not purification. You must bear in mind that during storm you send in a very large volume of effluent into the river, and if you calculate the amount of polluting matter it is a very large amount; in view of that I do not think it would be wise to adopt a too stringent standard. That is one of the reasons, and one of the strong reasons I have against adopting this definition straight away.

6098. (*Mr. Power.*) Have you made any examination of any storm water overflows on your plan?—I have made examination of a few, to ascertain that dilution is not purification. Although you may have a storm sewage showing ·4 oxygen absorbed, yet that effluent is capable of eating up the dissolved oxygen of nine volumes of river water, and by keeping the limit at one, there is no saying what you may be able to do eventually. This is the way I am looking at it just now; it may turn out that instead of having to lower your standard of 1 you may have to induce the authorities to take in more storm sewage for treatment, but it would be rather hard on the authority if you fixed this rigid scientific standard of half-grain oxygen absorbed or this definition of a non-polluting effluent. If you were to make that rigid now, I question whether you could call upon authorities to treat larger volumes of storm sewage.

6099. (*Professor Ramsay.*) It appears to me from what you say that it is quite likely that authorities will dodge your standard by diluting their sewage?—They cannot dilute it; they have no water to do it with.

6100. I am thinking of the country districts?—They are worse off than the towns for dilution; how can they dilute it?

6101. By turning it into a brook—mixing it with a brook?—That does not matter; the effluent should be analysed before it enters the brook. Have nothing to do with the volume of water it discharges into. Deal only with the effluent as discharged.

6102. (*Colonel Harding.*) I was not able quite to follow all the discussion—the expert discussion with Professor Ramsay; what is your definition—would you mind repeating it for me—your definition of a non-polluting effluent; I understood you to say that it was an effluent which did not absorb more than half a grain of oxygen from permanganate in four hours, and did not absorb more than two grains of dissolved oxygen from a mixture of one of effluent to nine of tap water. Was I right?—Quite right.

6103. Was there any other item?—An effluent that does not appreciably destroy nitrogen in the form of nitrates when added to the effluent, when acting for forty-eight hours at 75 degrees.

6104. Those are the three points?—Yes.

6105. Then that third point, and, possibly, the second are somewhat difficult of experiment for persons in charge of sewage works who are not quite scientific?—Yes. You would have to have a trained chemist to carry out such tests.

6106. Then you have a pretty general confidence in the effluent which did not absorb more than half a grain?—Yes.

6107. If it were possible to ascertain in any simple way the amount of dissolved oxygen not in such a mixture as you have indicated, but in the effluent itself, and if that dissolved oxygen approached, say, 5 c.c., would not that take the place of the more complex tests that you were proposing before?—No; because you might have it there, but you must take the rate at which it disappears.

6107*. (*Colonel Harding.*) Let me put it in this way: supposing you have an effluent which did not absorb more than half a grain of oxygen from permanganate in four hours, which showed dissolved oxygen before incubation, say, 5 c.c., and which after incubation had not materially reduced that, you would consider those conditions thoroughly satisfactory?—Yes.

6108. Then if there was an easy means of testing dissolved oxygen in an effluent undiluted with tap water before and after incubation, you think that would be a valuable test if such a test could be shown?—Yes; I want to have a purely chemical test, and I insist upon a purely chemical test along with the bacterial test, because if you only rely upon the bacterial test or upon the power of the effluent to remove dissolved oxygen you have only to put one part of mercuric chloride to one hundred thousand parts of the effluent to stop the whole of the bacterial action.

6109. Mr. Scudder, the point I want to get at is this: would the estimation of the dissolved oxygen in the effluent unmixed with tap water before and after incubation, serve the same purpose as the test mixed with tap water?—No, you could not get an effluent which would carry in its own volume sufficient oxygen.

6110. Do you mean that there would be no effluent which, containing 5 c.c. of dissolved oxygen before incubation, would not wholly lose if after incubation?—It would lose it all in twenty-four hours.

6111. Have you tested that yourself?—Yes, sir; I have a host of experiments here showing the very best effluents; oxygen absorbed ·34 absorbs 15 cubic centimetres of oxygen, viz., the dissolved oxygen contained in its own volume together with one volume of aerated water.

6112. Then you find in practice that whatever dissolved oxygen is in an effluent is after incubation invariably lost, so that you add oxygen by adding tap water; that is your object?—Exactly.

6113. Then that definition you have given us of a non-polluting effluent is a sort of standard of perfection towards which we might aim as an ultimate thing?—Yes; you see there is no limit to the perfection to which you can purify sewage.

6114. It is not, of course, drinking water?—It is far from being drinking water.

6115. An effluent which reached your standard is an effluent which, flowing by itself through the country to a stream, would be unobjectionable?—Quite so.

6116. Now the provisional standard that you were proposing of one grain oxygen absorbed from permanganate in four hours, you did not accompany with the other test of oxygen absorbed from a mixture of one to nine tap water in forty-eight hours, did you?—Yes, I have given those results.

6117. But your present Mersey and Irwell standard is one grain oxygen absorbed in four hours?—Yes.

6118. Do you propose to add to that standard any standard connected with the absorption of oxygen from a mixture of one to nine tap water in forty-eight hours?—No.

6119. You do not propose to do that?—I do not propose to do that; I allow my opponents to do that if they like, only they will find out that the dissolved oxygen and nitrates disappear with effluents that infringe the one grain standard.

6120. You are quite satisfied with a simple standard of one grain of permanganate in four hours?—Yes, but if I was going into Court with one grain, I would be prepared to show that the effluent was capable of absorbing the dissolved oxygen of aerated water and the nitrogen as nitrates in forty-eight hours; I should rest upon that.

6121. You spoke of having made some analyses from the Whittaker and Bryant filters?—Yes.

6122. And you told us, what we already know, that that effluent contains a good deal of solid matter in suspension, and that, exclusive of such solid matter, it is above the Mersey and Irwell standard?—Yes.

6123. I understood you to say that after settling such matter it was within the standard?—Yes.

6124. Do you remember how much within, from the samples you took?—Yes. In the original sample the albuminoid ammonia was 0·144, and ·068 in the settled effluent, that is a little more than half the limit of our standard, our standard being ·1. *Mr. F. Scudder.* 13 Nov. 1900.

6125. You would consider that good?—Oh, certainly good.

6126. And if at Accrington they had settling tanks or filters to remove those suspended solids, the results seem to you to be likely to be satisfactory?—They comply with all the standards which we have discussed to-day. For instance, that effluent is an effluent which is capable of maintaining nitrates in solution; it does not lose the nitrates. It is incapable also of absorbing dissolved oxygen from aerated water.

6127. And it possibly itself contains a good deal of dissolved oxygen?—It would contain not more than seven cubic centimetres to the litre.

6128. It might, but it does, as a fact, contain probably four or five c.c.'s?—It will contain that.

6129. The presence of that amount of dissolved oxygen is, of course, a good feature?—Oh, a good feature of it certainly, and the presence of that amount of nitrates which is produced naturally there is also a good feature.

6130. Have you noticed whether the effluents from contact beds contain as much dissolved oxygen?—No, they do not; they are free from oxygen most of them.

6131. From some of these effluents probably reaching your standard in regard to absorption of oxygen from permanganate in four hours, yet not containing any dissolved oxygen at all?—Exactly, and containing no nitrates. The difficulty with a contact bed is to get nitrates formed, because you can only form nitrates during the period of rest, and that is why the Whittaker and Bryant filter from a scientific point of view is superior to a contact bed, that you bring about more rapid oxidation; in the contact bed you have to rely simply on the stored oxidised matter in the filter, but in the Whittaker and Bryant a more continuous oxidation is carried on.

6132. I want to press this point, Mr. Scudder; we are very anxious as a Commission to find if it is possible to get some simple test which the unlearned in small sewage works could carry out?—Yes.

6133. And this permanganate test, which you propose, you think is such a test as could be carried out?—I have taught about a dozen working men to use it, and they use it regularly; they are not chemists.

6134. If there was a simple means of estimating the dissolved oxygen in the effluent itself, you do not think that that would have much value?—No, because it is necessary to determine it scientifically if it is to be of value.

TWENTY-FIFTH DAY.

Wednesday, 14th November 1900.

PRESENT:

The Earl of Iddesleigh (*Chairman*) *presiding.*

Sir Michael Foster M.P., F.R.S.
Major-Gen. Constantine Phipps Carey.
Colonel Thomas Walter Harding.
Mr. Thomas William Killick
Mr. William Henry Power, F.R.S.

Mr. F. J. Willis, *Secretary.*

Dr. Hector MacLean Wilson, M.D., B.Sc., recalled; and further Examined.

6135. (*Chairman.*) You are Chief Inspector, I think, of the West Riding of Yorkshire Rivers Board, and you have got under your supervision about 240 sewage works and farms?—Yes, my Lord.

6136. Well now, will you give us your opinion as to whether land of all kinds, when used alone and without the artificial addition of chalk, cinders, or other material will purify domestic sewage?—I think that some kinds of land are quite unsuited for purifying sewage. If you have a sufficient area, any kind, I believe, of soil will purify sewage; but the area required of certain clay lands is so enormous that it is impracticable to purify sewage upon such land. *Dr. H. McL. Wilson, M.D., B.Sc.* 14 Nov. 1900.

6137. But on a hard clay land, would not the sewage run over it altogether? Would a very hard clay purify it at all?—Scarcely at all.

6138. Scarcely at all?—I should like, my Lord, to point to this sample of soil which has been furnished me by the Surveyor to the Morley Corporation. It is taken from the site of their sewage farm. A large scheme has been sanctioned by the Local Government

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Board, and is now being carried out, but the soil is so wholly unsuited for purifying sewage that the Corporation now intend to approach the Local Government Board to ask their sanction to putting in artificial filters instead of the land treatment which has been sanctioned.

6139. And are they going to ask the Local Government Board to sanction artificial treatment without any land treatment whatever?—Well, no, my Lord; they have the area of land required by the Local Government Board, but I fancy it is only to satisfy the Local Government Board that they have that area. I believe that it would be quite impossible to purify the sewage of Morley even after efficient chemical precipitation, which they proposed, on the land; the area, in view of the nature of the soil, is altogether inadequate. I would like, my Lord, to point out to the members of the Commission the nature of this soil. This is a section taken through the soil of the site of the farm, and I saw several trial holes opened. The soil all over the farm is of the same nature, and it is a very common kind of soil in the West Riding. This is the surface of the ground, and you see from the colour here there is probably about three, four, up to six inches of soil; the rest is wholly impervious to water, and, as I have frequently seen, if water is put on soil like this, it will lie practically until it evaporates.

6140. (*Major-General Carey.*) Of course, that soil can be improved, as was suggested, I think, in one of your answers, by mixing; either digging it out, burning it, and replacing it, or mixing it with cinders?—Yes, that is so; but as it is, it is wholly unsuited for sewage purification.

6141. (*Mr. Power.*) What was the area of land of that description available there for surface irrigation; it was enormous, was it not?—About 36 acres, I think, for a flow of 3,000,000 gallons per day. I should not like to be positive about those figures; I have not the exact figures.

6142. Have you had any experience in the West Riding of land made suitable, even when it was unsuitable? Do you know anything as to its cost?—Yes, sir, I have particulars in one instance. In the case of Ossett the cost was £140 an acre, and what was done in that case was to remove 18in. of soil from the surface of the land and to take out the next 18in., burn it, and replace it mixed up with the upper 18in.

6143. (*Colonel Harding.*) That was 3ft., then, Dr. Wilson?—That was 3ft. that was removed.

6144. Was not that a serious cost?—It was £140 an acre in that case.

(*Mr. Killick.*) Labour must be very cheap there.

6145. (*Mr. Power.*) That £140 includes the burning and replacing?—Yes; that was the contract. The engineer himself said it was very low, and his estimate was £180 per acre.

6146. (*Major-General Carey.*) What was the previous treatment before putting it on the land?—Chemical precipitation only, no artificial filtration.

6147. (*Colonel Harding.*) It would be interesting for you to give us the result of this improvement of the land that was made at Ossett?—I am sorry to say the result has been very bad, and apparently the land in that case is relapsing into its original condition.

6148. Consolidating?—Consolidating again. But the circumstances are very peculiar there, because the sewage is highly acid sewage, sir. In the Ossett district there is a great deal of carbonising and dyeing; very much of the acid effluent is discharged into the sewers, and the sewage itself is almost always strongly acid in reaction, and no doubt the acid, which is chiefly sulphuric acid, would act upon the clay and tend to bring it back to its original condition.

6149. And act also on the bacterial life by which the changes are brought about in the soil?—Exactly; the result is that the effect of the land treatment upon the tank effluent is very slight, indeed chiefly in the way of removing suspended matters. There are other instances, sir, pending. For instance, in the case of Horsforth, I know that the Local Government Board have asked the District Council to deal similarly with the upper 3ft. of their area of land, and in the case of Ossett, another outfall. The previous outfall is called the Spa outfall. Their other outlet at Healey is to be extended, and the soil is to be dealt with in something of the same way.

6150. (*Mr. Power.*) Your experience is that the land quickly reverts to the state of the land in its original condition?—I am only speaking of the experience of this one place, where the sewage is peculiar.

6151. (*Chairman.*) Is that the only case in which you have had experience?—Of that, my Lord.

6152. I mean, is it the only case where the land has been broken up and made into a sort of artificial filter bed that you know of?—Where it has been removed and burned.

6153. You may call that a sort of turning the land into an artificial filter?—It has been done on a small scale in several other farms; for instance, at Featherstone, where the soil is of the same nature as this, it was done in the large beds, which were practically formed into bacteria beds.

6154. Well, and did they succeed?—They produced a very good effluent, and they did not seem to revert to the original state. The burned ballast still apparently remains.

6155. And they are in work still?—They are at work still.

6156. And how long have they been going on?—They must have been going on now for two years.

6157. (*Mr. Power.*) And the particular land that did revert; what lapse of time was there between its burning and its becoming to be decidedly unsatisfactory again?—It began to revert to its original condition, I should say approximately about two years from the time it was dealt with.

6158. (*Mr. Killick.*) No cinders or refuse were added to the burned ballast?—Not in that case.

6159. (*Major-General Carey.*) Of course, it does materially affect the question whether the ballast is well burned?—Oh, it must make all the difference.

6160. In the one case you get a very hard filter material and in the other case a filter material which is ready to revert to its original condition?—In the one case it would approximate to the form of broken bricks.

6161. (*Mr. Power.*) I should like to ask, in this connection, Dr. Wilson's experience of peat. You have some peat land, not wholly peat moorland, but peaty areas rather. What is your opinion as to whether such land can be dealt with satisfactorily?—I am afraid, sir, I cannot give you any experience in that direction. We have some farms upon which small areas are peaty.

6162. Part of the area is peaty, and is that avoided for sewage disposal purposes?—No; it is used along with the rest of the farm, but they are only very small areas. There is no distinctly peaty farm that I can remember in the West Riding.

6163. Is that for broad irrigation?—For broad irrigation.

6164. And is the tendency to a clogging on the surface more conspicuous there, do you think decidedly, than at other parts of the farm?—I think not, sir; it seems to act just as the rest of the land does.

6165. It is greatly less pervious, I suppose?—Yes; it will be less pervious, but I have not sufficient information to speak as to that. There are only very small areas at certain farms that are peaty.

6166. (*Chairman.*) Then speaking generally, you could only say that land was suitable for purifying domestic sewage if it were land of a suitable character?—Yes, entirely.

6167. Have you formed any opinion as to this: Do you think that it depends entirely on the amount of filtration, or do you think there is a difference between different kinds of soil; that is to say, supposing you get a fine sand and a fine gravel, so that the amount of filtration was equal, do you think the difference between sand or gravel or any other kinds of filter would make any difference, or is it merely dependent on the amount of filtration?—I think, my Lord, it depends entirely upon the porosity of the soil. The nature of the soil makes very little difference indeed, or none.

6168. It is just the amount of filtration that it receives?—Yes.

6169. It does not signify much what it is filtered through, but it is the amount of the actual filtration?—Yes; the nature of the soil has in my opinion very little to do with it.

6170. (*Colonel Harding.*) Except mechanically?—Mechanically only.

6171. (*Major-General Carey.*) Then I suppose in gravelly soil, which is the second class which is unsuitable as being too porous, the result is to a great extent mechanical; there is no time for bacterial action to take place?—That depends very much upon the drainage. If the drainage is very rapid the filtration will be mechanical, but if there is no underdraining then you get a slower action and bacterial effect.

6172. What relation has subsoil water to the surface which seriously interferes with efficiency of the land for dealing with the sewage? I suppose you have samples in some parts where the subsoil water is within a foot or less of the surface; has such land been used for sewage disposal?—I am afraid I have no experience that would guide you in that, sir, because in such cases the subsoil has always been underdrained. I do not remember of any farms upon which the subsoil water approaches so near the surface.

6173. Which is not underdrained?—Which is not underdrained.

6174. What amount of subsoil from the surface would in your opinion demand underdrainage for that reason alone?—I think you should have at least an effective depth of 3ft. for the purification of the sewage—a minimum of 3ft.

6175. (*Chairman.*) When you say that the effluent is well filtered, what do you exactly mean; do you speak of effluents that you have analysed?—In connection with which, my Lord?

6176. Take a case; we will assume a case where you say the land has filtered the sewage well; well, the effluent is good. When you call it "good," does that mean that you have analysed it?—Oh, yes; I should not call an effluent good unless it had been analysed and the result found good.

6177. Analysed chemically and bacteriologically, or only chemically?—Only chemically.

6178. You would not be able to tell us of your own knowledge anything of the bacteriological contents?—No, not of my own knowledge. I have not begun to carry out any bacteriological examination of effluents.

6179. Would you mind giving me your definition of broad irrigation?—I was rather, sir, going to ask the Commission what broad irrigation meant. There seems to be no definite line of demarcation between broad irrigation and intermittent filtration.

6180. (*Major-General Carey.*) But is not intermittent filtration an intermediate step between broad irrigation and artificial filtration, that is to say, between the disposal of sewage on a large area and an artificial filter where the maximum of sewage is concentrated?—I think there are, sir, certain cases that you could show were definitely cases of intermittent filtration, for instance, where the land is laid out in plots with banks all round, and the sewage is run upon those plots, and after a charge has been put upon the plot the sewage is allowed to stand until it filters away; that is definitely intermittent filtration.

6181. That is as proposed originally by Mr. Bailey Denton?—That is so. On the other hand, you have some instances which are certainly broad irrigation, where, as at Harrogate the Commission saw, the sewage is allowed to run over the surface of the land and gradually lose itself by percolation and evaporation. That is broad irrigation, but there are all sorts of intermediate kinds of treatment between those two.

6182. But at Harrogate they would never call it intermediate downward filtration?—No; you have the extremes no doubt, but there are a great many intermediate methods which might be put down to one or might be put down to the other. For instance, in many farms the plots are cultivated by means of trenches, and the sewage is run into the trenches between plots, say of a yard wide or 4ft. wide, and there it is treated practically by intermittent downward filtration, and does not reach the surface of the plots.

6183. But even in a broad irrigation area there is an intermittency, because the sewage is not continually irrigated on the same area?—That is so.

6184. Because it is shifted from one area to another, and it is doubtful whether that would be a fair sample of intermittent downward filtration. Unless the land is specially laid out for downward filtration it would come under the head of broad irrigation, I think. And then there is another point, the volume of sewage which is put upon the area?—I have found it exceedingly difficult to divide the sewage farms into the one method of disposal or the other.

6185. (*Mr. Killick.*) Would you describe as broad irrigation land treatment on land which is underdrained?—I do not think that enters into it, sir, because whether the land is underdrained or not, you might have intermittent downward filtration if there was a free natural subsoil drainage.

6186. (*Major-General Carey.*) But there is a great difference between the volume of sewage which may be put upon an area laid out on the principle of broad irrigation, and an area laid out for intermittent downward filtration theoretically?—Oh, yes, a great deal more can be put upon a plot laid out for intermittent downward filtration.

6187. Properly drained, than could be put on a broad irrigation area?—That is so, sir, and on many farms—for instance, in the case of Keighley, which is laid out for broad irrigation for crop growing and for the sewage to be distributed gradually by irrigation over the plots—they have a larger amount of sewage than the farm can very well deal with on that system, and their practice is to set aside certain plots and use them for intermittent downward filtration; flood them enough, and then let them rest until the sewage has gone, and then flood them afresh.

6188. In fact, there is very little difference between a plot laid out for an intermittent downward filtration and an artificial filter?—The material is different.

6189. The concentration of sewage is rather more in the one case than in the other?—It is, if one may call it so, a natural artificial filter.

6190. (*Chairman.*) Have you considered the question of storms where the amount that goes on to the land is very much larger than normal?—Yes; but I am afraid, my Lord, I have no very definite information to give you on that point, because I find that in very few cases can I get definite information as to the amount of storm water that reaches the sewage works. In the older and larger schemes they are provided with so many storm water overflows, and they take in so much surplus water, and they have so few gaugins of the sewage flow that very little definite information on the subject is to be obtained.

6191. Do you know of any local authority actually treating six times the volume of its normal flow?—I am afraid I do not, my Lord; I think the information is not definite enough on the subject; it would require very careful gaugings over a long period to ascertain in the first place what is the dry weather flow; it is very difficult to obtain that in any case; and then it would want very careful gaugings in times of storm to see what the flow at such times is, and the figures are not available at any place that I know.

6192. (*Mr. Power.*) Have you any information as to the capacity of the outfall sewer—the volume of sewage that it would accommodate in times of storm?—In relation to all new schemes, by attending the Local Government Board inquiries, we get to know the capacity of the main outfall sewer, and that invariably is more than sufficient to take six times the normal flow.

6193. More than sufficient?—Yes.

6194. Those are new works?—Those are new works. In the case of old works——

6195. You would not say the same for older established works?—No, I could not. The only information that I have been able to obtain on the point is in connection with Leeds, where at the Sanitary Congress in Leeds, in 1897 I believe the meeting was, Mr. Silcock read a paper giving gaugings of the sewage flow at certain times in dry weather and in times of storm.

6196. (*Major-General Carey.*) You have not seen any schemes carried out within the last two or three years with bacterial filters?—There is only, I think, one place that I know of where a complete scheme has been carried out; that is at a colliery village in Hemsworth Rural District—South Elmsall. I beg pardon, Sir, that is not a complete bacterial scheme, because they have land provided there.

6197. Of course, you are aware that by the requirements now made by the Local Government Board the sewage and storm water have to be treated in some way up to six times the dry weather flow, and all schemes which have been approved within the last few years will be carried out on those lines?—Yes.

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6198. I suppose you have not seen any of them actually at work?—No, none so recently as that.

6199. Have you any observation as to the rate of flow in the sewer at which storm overflows begin to come into operation. You say there are a great number of storm overflows; does the rate of flow at which the weir operates vary very much in different sewers and different districts?—I am afraid I have not definite enough information on that point. The storm overflows I find begin to act in dry weather very frequently, and they act on very slight provocation in time of rain.

(*Mr. Killick.*) Especially in darkness?

6200. (*Chairman.*) Now in the case of most sewage farms that you are acquainted with are there storm overflows at all or does the whole go over the land and take its chance?—Almost without exception there are storm overflows.

6201. With farms—sewage farms?—Yes, you are referring now to the storm overflows on the farms.

6202. Yes?—There are, of course, storm overflows usually provided on various branch sewers. For instance a sewer coming from a high level district into a low level sewer is very frequently provided with a storm overflow before it reaches the low level sewer. There are in addition nearly always storm overflows provided just as the sewage reaches the sewage farm, and the only exceptions that I know where there are no storm overflows on the system are quite small places in the country, where there is a comparatively large area of land for dealing with the sewage, and where the sewers are as strictly as possible on the separate system, not taking in the storm waters.

6203. Have you any facts as to the range of volume there in 24 hours?—I am afraid not, sir.

6204. Between dry and excessive wet?—I am afraid not, sir.

6205. (*Mr. Killick.*) Would it be possible to keep storm overflows under observation and to ascertain how often they come into operation and the extent of the storm overflow?—It would require, sir—to be of any service, the information obtained in that way would have to be taken over a long period, and very regularly. Of course that I think rather lies within the province of the surveyors of the different authorities than within the province of the Rivers Board. In fact we could not, unless by special permission from the sanitary authorities undertake such observations.

6206. Do you think if you asked certain selected sanitary authorities in your watershed they would consent to giving any observations?—I am quite sure they would, many of them.

6207. And if those observations were recorded in a certain number of cases in the West Riding and in a certain number of cases in Lancashire for a year we should then have some very reliable data?—It is very much what is wanted; there are, as far as I can ascertain, no reliable data on the subject.

6208. It might be well to ask your Rivers Board if they would do such a thing?—I would be very glad to do so if the Commission would kindly draw out a scheme upon which all authorities should work. It would be of service of course if we were working on exactly the same lines as Mr. Tatton, say on the Lancashire side, so as to make the results comparative. I should be very glad to set my inspectors to watch this, put up gauges, and have all reliable data obtained.

6209. I would suggest, my Lord, that it might be a matter of consideration whether the Rivers Board should not be asked to do that?

6210. (*Mr. Power.*) Have you made observations chemically, if not bacteriologically, as to what comes over these storm overflows which you have had under observation?—No, sir, the pollution has been so gross. I have at various times taken samples and made a chemical analysis, but I have almost invariably found what has come over the overflows to be practically the ordinary sewage.

6211. Chemically it offended any reasonable standard?—It did.

6212. It was polluting liquid?—It was a polluting liquid.

6213. A putrescible liquid?—I think if you will allow me I would like to put before the Commission my view that storm overflows are at best only a necessary evil, that what will escape by a storm overflow even in the time of very heavy rain will be of a polluting character.

6214. At the later stages of a very heavy rain?—I believe all through. I have never seen a storm overflow discharge any liquid, but what is evidently of a polluting character.

6215. From naked eye appearance, do you mean?—From naked eye appearance, and when we have taken analysis.

6216. And by chemical analysis?—Yes, I have not many chemical analyses, but I have some, and they have invariably shown the discharge to be polluting.

6217. (*Major-General Carey.*) When the storm overflow is at such a level that it can only come into operation when the sewage is diluted with five times its volume of storm water?—I could not speak definitely as to that, sir, because those regulations refer to the latest schemes and the observations that I have taken refer much more to the older schemes where the storm overflows come into operation very soon.

6218. Where they were allowed to put in the overflows at any level they pleased at the discretion of the authorities?—That was so, Sir.

6219. (*Mr. Power.*) But if the objectionable character applies to the late stages of the storm, where these overflows at slight provocation are concerned, is there not some indication of what would happen perhaps when a dilution of five volumes of rain water obtains?—I think you can judge that, sir, very well by the nature of the sewage reaching the sewage works in such cases, which is of course the same nature as discharged from the storm overflow, and in my experience that is invariably of a polluting character, even when so diluted by very heavy rains, and I think storm overflows probably are quite necessary merely on account of the expense of treating the very great volume of sewage that comes down in very wet weather.

6220. (*Major-General Carey.*) In unlimited quantity?—In unlimited quantity. In many cases not because it is pure enough to go to the streams, but because the expense of treating it would be so enormous.

6221. (*Mr. Power.*) Have you any data as to the chemical analysis of sewage when so much as six times the volume of dry weather overflow has been delivered in the previous 24 hours?—I have not any definite information as to the amount of sewage passing down.

6222. It would be an estimate always?—It would be very rough. There are no figures that I know of giving any estimate of the flow in wet weather.

6223. You have some analyses taken after heavy and long sustained storms I suppose, have you not?—Not many.

6224. Some hours later than the storm; when the overflow has been in operation for several hours, and presumably a very large volume has come down; have you any analysis of such sewage?—I have some analysis, and I found the weather records, but I have not co-related the two.

6225. It would be interesting if you had any facts of that sort?—I will look up the analyses I have, and look up the weather records, and if I can make a satisfactory table from which anything can be learned I should be very glad to put it before the Commission.

6226. (*Chairman.*) Would you be in favour of keeping rain and storm surface water out of the sewers if you could?—Keeping the storm water out.

6227. Well keeping rain water out of the sewers that convey the sewage. Would you be in favour of using them only for the sewage?—On the whole, yes. There are some circumstances, I have pointed, I believe, in my answers to certain of the towns where the rain water from the streets would be quite as polluting as sewage, in busy streets, paved streets, where there is horse manure and all sorts of refuse about, mud of all kinds, and the storm water washed off such streets will be quite as polluting, at the beginning of a storm at least, as any sewage.

6228. (*Colonel Harding.*) Therefore, in that case, you think it is not advisable that it should go direct into the river?—In such cases, no. In the ordinary cases, for instance in the outskirts of towns where the traffic is not so heavy and the streets are not so grossly polluted, I think for the matter of expense it is as well to keep the storm water out of the sewers, otherwise the flow of sewage at the sewage works becomes so enormously increased that it becomes very expensive to deal with it.

6229. (*Major-General Carey.*) Especially with a pumping system?—Yes.

6230. (*Mr. Power.*) You think in a big town water that comes off the streets on the first flush of a heavy

storm is as objectionable as that which comes from the back yards which are drained into the sewers. The roof and yard water commonly goes into sewers, when there is a separate system, does it not, whereas that from the streets and roadways is excluded from the sewers?—Yes, sir, but I think that is not because of the difference in pollution; is that not rather—I find it is so in the schemes brought forward—because of the difficulty of draining roofs and back yards separately. I should be inclined to say that the water from the main streets where there is heavy traffic will be much more polluting than what drains from the back yards and roofs, and I think it is on the question of expense again and the difficulty of draining the roofs and back yards separtely that they are taken in.

6231. Chemically it would be worse?—Chemically from the roads it would be worse.

6232. (*Mr. Killick.*) Do you not think now that the roads are so well made, polluting surface water from the rural roads is almost as polluting as from a town?—Oh, not to the same degree.

6233. Have you made any analyses?—No, I have not any analyses, I am sorry to say, but one can see. I have often watched what was discharging from the roads into the drains, either into the sewers or into the surface water drains, and it is very evident in the case of the centre of a busy town what goes from the streets is very grossly polluting. The whole thing, if I may be allowed to repeat, is a question of expense. I think what does drain from these roads, if there is any considerable traffic on them at all, is polluting, but if it had all to be treated and purified the expense would become unbearable.

6234. (*Major-General Carey.*) The cost of the sewers?—The cost of the sewers and the sewage works.

6235. And as regards the proposal for the treatment of the diluted sewage you do not apparently think it is necessary to appropriate any area of land for that purpose; but to put the whole of the sewage and the storm water over the irrigation area?—I should deal with it in exactly the same way as the ordinary sewage. Use all the farm for dealing with the mixed storm water and sewage.

6236. If you have a limited area, does not that overtax the farm to a very serious extent? Supposing you have an area in proportion, we will say, of an acre to 1,000 persons, or 30,000 gallons to the acre, six times that amount would be 180,000 gallons—180,000 gallons per acre?—Yes.

6237. And, of course, for a population of 10,000, and say ten acres, you would have 1,800,000 gallons to deal with before the storm overflows came into operation; 1,800,000 gallons would have to be taken on your ten acres?—Yes, sir, and I think I have pointed out my answer to a question that in such a case the land is probably already very waterlogged. It occurs in wet weather, when the land, from the natural rainfall, is heavily waterlogged, and it has been suggested, and is being carried out on several farms that special filters should be provided for dealing with the sewage in times of storm so as not to throw that large quantity of diluted sewage on to the land areas.

6238. You approve of a separation, then?—I think it is wise.

6239. And a separate treatment of the storm water?—I think it is wise because the land is scarcely able to take it, as it were.

6240. It comes to this, that if the area of land is calculated upon a given flow, and if the given flow upon which the area of land is based is the normal dry weather flow, it must be obvious that you cannot deal with storm waters upon that area?—That is so; you must provide other means.

6241. (*Colonel Harding.*) Without danger of dislocating the whole arrangement. And therefore, if it is proposed to deal with the storm waters to the extent of five times on the land, necessarily the area of land must be calculated upon the total volume of such dilutions?—That is so.

6242. Unless, of course, special provision is made to deal, as you suggested just now, by artificial filters or otherwise with the storm water?—It is obviously necessary to calculate your area of land upon the maximum amount of sewage that will be passed on to it.

6243. (*Major-General Carey.*) Sewage and storm water?—Sewage and storm water.

6244. (*Colonel Harding.*) Therefore, in your opinion, if that area is based upon the normal dry weather flow that area does not permit practically of a treatment of storm waters?—Certainly that would be so.

6245. Then as to the question of the overflows it has been suggested that they should come into action when you have six volumes, that is five dilutions of the sewage. In such case you may reckon that there would be a sixth of the impurities in such diluted sewage that there usually is in the dry weather flow?—Oh no, sir, I think that would be a mistake.

6246. I am quite aware that immediately after dry weather a storm carries down an exceptional amount of organic matter, but that is a condition which does not last long?—Well, I think it would last a considerable time; it does not mean that you get a sudden flushing, cleaning out the sewers and of the surface of the streets.

6247. Put it in this way, the amount of organic impurities coming down in such times is double what comes down ordinarily?—Yes.

6248. One might put it that with six volumes you would have about one-third of the organic matter?—The sewage would be one-third as strong in that case.

6249. In such times the river would necessarily also be swollen?—Yes.

6250. So that if you had six times the flow in the river, that you would have one-eighteenth in the river of the amount originally in the river in dry weather?—In proportion that would be so.

6251. Then do you think that, seeing storm overflows must necessarily come into operation sooner or later, because it is not financially practicable to deal with the whole rain-fall at the sewage works, you would consider that six volumes is a fair amount to name before storm overflows come into action?—I think, sir, that seems quite a reasonable figure to take; I would put it as high as possible.

6252. I am putting the area of practicability?—Yes; and the authorities are now, for the last two years, going in for sewage schemes, and providing their sewage works of that capacity, so that it is practicable, and I do think that probably it would be unreasonable to ask for any more, but, as I have said, not because the discharge at such times by the storm overflows is not polluting, but simply from the question of cost of dealing with it, and because the effect upon the swollen rivers is not so great.

6253. (*Major-General Carey.*) You would like to have a larger amount?—I should like to have it all.

6254. (*Chairman.*) Assuming a storm over-flow is a necessary evil, it should be as high as far as costs will allow?—That is exactly my position.

6255. Just a few more questions about the land; do you find that frost and snow affect purification?—I do not think at all, sir. I have no comparative figures to lay before you, because I am sorry to say that in the past there has been no definite record kept of the weather, but, speaking generally, the effluents analyse just as well in the winter time as in the summer.

6056. And have you found that cropping land affects its power of purifying the sewage?—It affects it, sir, in this way, that the land to be cropped must be all turned over and tilled, and thoroughly mixed, the part that has got sewage sick must be mixed thoroughly with the part which is clean, and it has to have certain periods of rest when the seeds are put in, when the crops are removed, and for certain crops while they are growing, so that all these things tend to make the land, renew it, and make it capable of a fresh dealing with the sewage even after it has become sewage sick.

6257. And do you think that there are particular crops better than others?—From my point of view, some crops are exceedingly bad, such crops as oats put the land out of sewage use for the best part of the twelvemonth, because I find that none of the managers of sewage farms will put sewage upon land which is growing oats from the time it is sown till the time the crop is reaped. Other crops can be used at various times, although some of them not constantly, and they may be divided into those that can be used constantly with sewage, those that can only be used for a short time during their growth, and those that cannot be used at all while they are growing.

6258. Then there are other crops that never necessi-

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tate the flow of sewage being stopped at all are there?—Ryegrass, for instance, excepting during the time—perhaps a week or ten days—when the land is being dried so that the workmen can get on to it to remove the crop. Ryegrass can be treated with sewage almost from the time it is sown, during its whole growth. Mangolds again, and on some farms they treat turnips with sewage pretty constantly until a few weeks before the crop is ripened for removal; cabbages and such plants can be treated with sewage the whole time if the sewage does not touch the cabbages. If the cabbages are grown on ridges so that the sewage does not actually touch the plants, the land on which cabbages are grown can be used the whole time.

6259. (*Mr. Power.*) Speaking generally, a sewage farm that is to be cropped will have to be larger relatively than one which is not cropped, will it not?—I do not think, sir, I would say that, unless the plots are being used by intermittent downward filtration.

6260. But you will have certain areas, if you have got oats for instance, put out of court for a considerable section of the year, you would have to provide for that in estimating your land, if you were to grow oats at all largely on the sewage farm?—I do not think, sir, oats should be grown on the sewage farm at all; I think it is a crop that should be forbidden on a sewage farm.

6261. Altogether, is it not a question of degree; why not limit the area to be sown?—I do not think, sir, more than would be required to rest these plots. If the land is properly cropped it should not be out of sewage treatment.

6262. The rest that is necessary to give to land would be about the equivalent of the land lying idle on account of the crop do you mean?—I believe so, sir.

6263. Then you would exclude oats; potatoes would you exclude?—Potatoes is another crop that sewage should not be put upon; it may be in very rare circumstances necessary to grow such a crop as oats and potatoes, but it can only be where there has been some neglect, and the land has become very sewage sick.

6264. And it has to be laid aside for some considerable period?—For a long time.

6265. (*Mr. Killick.*) Have you any reliable information about growing willows?—Willows do very well indeed; we have several farms in the West Riding; one the Commission saw at Ripon, and the results there have been very good; at Pateley Bridge and Otley, there are other willow plots, and they seem to do very well.

6266. (*Colonel Harding.*) Do you think the growth of the willows at Ripon facilitated the treatment of the sewage at all; suppose they had not grown willows at all; suppose the land was not expected to bear anything would not their treatment of sewage have been at least as good?—I think not, sir, because the willows growing so rankly as they do must remove from the soil a very great deal of the organic matter, the products of the bacterial action which must take place in the soil.

6267. Then you think that the growth of suitable crops actually facilitates the treatment of the sewage?—I am sure it does in that way.

6268. And may be looked upon in a way as a guarantee that the farm will not be overworked?—That is another reason. May I give you this instance, sir. On the Keighley Farm, as I have said, some of the plots are laid out for intermittent downward filtration because they cannot by broad irrigation get rid of all the sewage. These plots are used sometimes for 12 months without any crop at all; they are used really until the soil becomes sewage sick, but when they are then dried and tilled and planted say with mangolds or ryegrass, they become again immediately available for sewage treatment, for sewage disposal; the soil recovers itself, the plants remove from the soil the organic matter, and it reverts practically to its original condition. In fact, making inquiries of the manager there, who has been in charge for a considerable time—for many years—he says the soil is as suitable for sewage treatment now as ever it was, and even better. He pointed out a special bed that had become practically sewage sick, being used on that method for some time, and he said that having tilled that and sown it with ryegrass or mangolds it would become quite fresh and able to deal with sewage again as well as ever, so that I am sure the vegetation is of use.

6269. (*Major-General Carey.*) Is not one of the chief causes of failure of broad irrigation farms, even with suitable land, to produce satisfactory results caused by overdosing one part of the farm with sewage at the expense of the rest which is under crops for which sewage is not at the time required?—It is very often, and there are several farms in the West Riding where that neglect is very great. At one that I visited a short time ago out of some 53 acres which could have been available for sewage treatment there were only about 15 at that time because of the crops of oats and potatoes and the drying off of root crops, and of course sewage which could have been purified on 50 acres could not be purified on 15.

6270. (*Mr. Power.*) It was summer time I suppose, was it not?—It was late summer time—the time when the crops were ripening.

6271. (*Major-General Carey.*) And the tendency is for a sewage farmer to look at profits rather than purification of the sewage?—It has been so very much in the past, but of late I think the District Councils are recognising—most of them—that the sewage farm is not a profitable investment, and giving instructions more for the treatment of the sewage than for the cropping of the land.

6272. (*Mr. Power.*) What would have happened in that instance if they had had a very heavy storm; would they have put all on the 15 acres that they used, or put it by bypass into the stream?—That is what would have happened I am afraid; they would not have put it on their oats crop you may be quite sure of that.

6273. (*Chairman.*) Have you ever known any injury to health to come from the sewage farms?—Never, I think; I think in my four years that I have been in the West Riding I have known of one manager of a sewage farm being laid up with typhoid, but I cannot say it was due to the farm at all, and as a rule they are exceedingly healthy men.

6274. (*Mr. Power.*) And as to the cattle that are kept in connection with the sewage farms or fed with sewage-grown produce, have you any facts as to whether they suffer? I have known several instances where dairy cattle drinking sewage-polluted water—perhaps that is not quite the question you put.

6275. The crops of the farm used for feeding—cows we will say fed on rye-grass?—No; quite the contrary. For instance, just the other day I inquired at the Dewsbury farm where they have a herd usually of some 40 dairy cattle fed on the produce of the farm, and not one has been lost in four years of these dairy cattle.

6276. Then the ryegrass from the farm is not given, I suppose to the cows until it has ceased to be actually treated with sewage; sewage is not run over the ground for some time before the grass is cut?—Of course the ground must be dried off before the workmen can get on to cut it, and usually I should say the sewage is kept off—depending upon the weather—for a week or a fortnight before the ryegrass is cut.

6277. Before they go on to cut it?—Yes.

6278. (*Chairman.*) Do you know anything of watercress in connection with sewage farms?—I have none in the West Riding, so far as I know.

6279. Do you know any sewage farm where the pasture is used?—Yes, there are several.

6280. There, I suppose, the cattle feed on the grass just as they would in an ordinary grass field?—Yes.

6281. And you have never known any harm come from that, I suppose?—No, I have not known of any harm.

6282. In fact, the only harm to any cattle you know of came from sewage-polluted streams?—From a stream polluted by the effluent from sewage works which was not satisfactory.

6283. But as far as you know, there is no reason to suppose that feeding on the grass grown on a sewage farm would do any harm at all?—I have never known an instance.

6284. (*Mr. Power.*) In the case of the milch cows drinking from a sewage effluent; did it affect the quantity of milk they yielded or make them seriously indisposed in some other way?—I believe this is the method of hurting them, sir. It sets up diarrhœa, and it makes the cows drop their calves and brings them into a low state of health, and I believe they are very apt to take tuberculosis.

6285. Do you mean more susceptible than they otherwise would be?—It may either be that, sir, or it may be that they get the infection from the sewage.

6286. From crude actual sewage?—I could not say; I have no experience to show, but experiments have been carried out to show that tubercular germs are liable to be discharged into effluents, and are present in the unpurified sewage, so that it looks to me a very likely source of infection for the cattle.

6287. Do you think that as a fact cows on sewage farms do suffer more from tuberculosis than other cows in the same district; are there any veterinary statistics of that?—I do not know of any reliable statistics; I am speaking rather from knowledge of one case especially—two perhaps, but in one case that was the course of events—that out of a certain number of dairy cattle fed in a field through which a polluted stream ran they began by scouring, dropping their calves, and ended by becoming tuberculous.

6288. Was this stream polluted by effluent or by raw sewage?—Chiefly from the effluent; there was also a little raw sewage, but the chief pollution was the bad effluent from a sewage works.

6289. Did the effluent form a considerable bulk of the total volume of the little stream, do you think?—Yes, it would be on a rough estimate about one-sixth.

6290. The dry weather average?—In dry weather.

6291. (*Mr. Killick.*) Was it a chemically treated effluent?—No, it was a biologically treated effluent, but very imperfectly treated, for the most part by one contact.

6292. (*Chairman.*) Was it domestic sewage?—Domestic sewage wholly in that case.

6293. And it had gone through one filter bed, had it?—For the most part.

6294. (*Mr. Power.*) Is it the notion of farmers generally, do you think, that if sewage gains access to the stream from which their cattle drink it is deleterious to the health of the milch cows?—I think it is recognised generally by veterinary surgeons and farmers that it is very apt to make cows drop their calves—to make them scour and drop their calves.

6295. Drop their calves as the result of their scouring?—That is what it is usually put down to; yes.

6296. (*Chairman.*) Taking this case for the moment that you speak of—does that effluent still go into that stream, or has anything been done to improve matters?—There is a Local Government Board Inquiry this week, my Lord, for improving the sewage works, increasing and enlarging the sewage works.

6297. But this case that you speak of has been going on for some years, has it?—It is rather a hard case, because about three years ago the sewage works were constructed; they were not sufficient, they turned out to be not sufficient, and the authority has now to enlarge and improve them.

6298. Yes, but what I wanted to know was whether this has been going on for some time, and whether there was only one particular case where the cows were affected, or whether there have been several cases?—I have not the details in many cases, but I have frequently heard of similar cases.

6299. In this particular stream and field that you speak of?—Oh, no; in this case it has been repeated for several years; two or three years at least the experience has been the same.

6300. Two or three years running cows have suffered from drinking this?—Yes, when put into this field.

6301. (*Colonel Harding.*) Returning to the general question, what is your opinion as to nuisance arising in connection with sewage farms?—It depends, I think, sir, entirely upon the management of the farm: if a farm is well managed there should be no nuisance.

6302. Well, as a fact, taking Doncaster, there is at times considerable nuisance even from that well managed farm, is there not?—I think not, sir. We have had a report of nuisance from the sewage being allowed to lie stagnant upon some of the fields near the road, but there have been no such reports lately. There has been a change in the management, and I think since the change in the management I have not heard of any complaints.

6303. Then where nuisance arises—and of course nuisance does arise sometimes in connection with these farms—is that nuisance due, do you think, to the decomposition of the solids coming down with the sewage rather than from the impurities in solution?—I think it is entirely due to the decomposing solids upon the surface of the ground.

6304. Are there cases where you think it is advisable in the first instance to settle the solids before the sewage is passed upon the land?—It seems to me generally advisable, unless there is a very large area of land available, to take out the bulk of the rougher suspended solids before passing it on to the land.

6305. I take it that the action of the land is this: that the liquid passes down into the land, and that the changes or putrefaction that arise occur within the land, whereas in the case of solids these remain on the surface of the land and the gases evolved pass away at once into the air, and also the action would probably be much more rapid, owing possibly to the heat of the sun?—That is so; and if too many of these solids are not put on the land, if there is a sufficient area of land to deal with the sewage, that can be carried out without the nuisance arising, but if any slight excess of solids is deposited on the surface of the land, and especially if the land is of such a texture that it becomes choked with these solids, then a nuisance does arise, and it would be better in my opinion to remove these solids by a preliminary rapid settlement rather than throw them on to the surface of the land.

6306. (*Major-General Carey.*) Or even by rough screening?—Or even by rough screening, or by both.

6307. (*Colonel Harding.*) Then you have been able to ascertain how far trade refuse being mixed with sewage causes difficulties to arise in land treatment? Of course one knows that certain trade refuse cannot be dealt with on land, but to what extent do you find that land can be used with trade effluents?—I have prepared a short Table here, sir, and I wish rather to point out to the Commission that the common idea that sewage with trade refuse in it is strong sewage is a mistake from my experience. The sewage of towns taking in trade refuse is very often weaker sewage than the sewage which is purely domestic; and further than that, the last Royal Commission gave a Table of sewage of water closet towns and sewage of privy midden towns, showing that they were approximately equal in strength; but my experience in the West Riding goes to show that the strongest sewage we have to deal with, with one or two exceptions the strongest sewages we have to deal with, are the sewages from privy midden towns from colliery villages. I would ask you to look at this Table, sir.

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DOMESTIC SEWAGES FROM WATER CLOSET TOWNS, AND FROM PRIVY MIDDEN TOWNS, AND SEWAGES MIXED WITH TRADE REFUSE.

(Results expressed in Parts per 100,000.)

Sanitary District.	Solids.			Chlorides as NaCl.	Ammonia.			Total Oxygen absorbed at 80° F.		Oxygen absorbed in Solution only.		Remarks.
	Total.	In Suspension.	In Solution.		Free.	Albuminoid (Wanklyn).	Albuminoid in Solution only.	Three Minutes.	Four Hours.	Three Minutes.	Four Hours.	
					Sewages, including W.C.'s.							
Ripon City	73·2	28·2	45·0	7·02	1·52	0·68	0·25	1·36	4·72	0·70	2·36	Taken 3rd October 1899—2 hours' average (12.30–2.30).
Dewsbury Borough	—	—	—	11·91	—	—	—	—	3·11	—	1·21	Taken 2nd to 8th February 1899—average of seven daily samples.
Heckmondwike	—	—	—	14·40	—	—	—	—	10·50	—	5·30	Taken 2nd to 8th February 1899—average of seven daily samples.
					Sewages, not including W.C.'s.							
Rotherham Rural (Canklow)	555·0	341·0	214·0	145·1	3·84	3·70	0·32	—	25·1	—	2·24	Taken 15th February 1900—3 hours' average (9–12 a.m.).
Oakworth	299·4	220·76	78·64	11·70	9·71	5·81	1·10	—	39·19	—	6·41	Taken 6th June 1898—3 hours' average (9–12 a.m.).
Hunslet Rural (Middleton)	—	—	—	14·62	—	—	—	—	18·3	—	7·1	Taken 31st October 1900—1 hour average (9.45–10.45).
					Sewages, including Trade Refuse.							
Leeds	137·2	52·2	85·0	20·47	3·49	1·56	—	—	8·64	—	—	Taken 30th November 1897—2 hours' averag .
Huddersfield	152·6	50·4	102·2	43·9	2·0	0·75	—	—	9·55	—		„ 13th March 1900.
Sheffield	93·9	35·5	60·4	16·67	3·14	7·29	0·183	—	4·71	—	1 ·8	„ 6th June 1898—3 hours' avera,.e (10–1 p.m.).
Pudsey	—	—	—	30·42	—	—	—	—	21·3	—	14·9	Taken 6th November 1900—2 hours' averaje (12.40–2.40).
Keighley	—	—	—	12·87	—	—	—	—	5·44	—	—	Taken 13th December 1899—2 hours' averaje (2–4 p.m.).
Bradford	313·0	189·0	124·0	17·0	5·91	2·45	—	—	25·0	—	—	Taken 27th September 1900—(from "mixing tank").

6308. (*Mr. Power.*) Where the middens are undrained to the sewers?—Where the middens are undrained.

6309. (*Colonel Harding.*) In that case how did these matters get into the sewage?—Simply in the slop water in the case of non-water closet towns.

6310. Then they do not get into the sewage these matters?—The fæcal matters?

6311. Yes?—I think to a considerable extent they do, because it is the habit of the people, in these colliery villages especially, to empty a considerable proportion of their slops, urine and probably fæces too, into the slop water drains.

6312. Fœcal matter is kept out of the drains?—Not all, sir.

6313. But the bulk of it?—Probably the bulk of it is.

6314. And nevertheless such sewage is very strong?—Very strong indeed. And it is strong because there is no admixture of trade effluents and no admixture of water as there is in the case of water closets. I would ask you, sir, to look at the Table, and the first three are samples taken at random from some of my analyses of water closet towns—Ripon, Dewsbury, Heckmondwike. The next three are samples of sewages also taken at random from towns with privy middens only, and the next lot are samples of sewage mixed with trade refuse, and you will find that the strongest of all is one of the samples from a privy midden town, that all the three from the towns that have only privy middens are very strong indeed.

6315. What are you measuring the strength by—chlorine?—From the organic matter rather—the albuminoid ammonia where it is given and the oxygen absorbed. You will find that the albuminoid ammonia is given in most instances both on the whole and in matters in solution.

6316. (*Mr. Power.*) Sheffield is very high I see in albuminoid ammonia?—Yes, Sheffield is very high, Sir.

6317. (*Mr. Killick.*) We had a case the other day, Rochdale, where they had been turning into the sewers refuse from the pail system, and the sewage immediately became infinitely worse; of course that would be in accordance with your observations?—Quite so, and there would be no dilution in that case, the contents of them would be added without any dilution such as they have in water-closets.

6318. That would be in accordance with your experience?—Yes.

6319. (*Colonel Harding.*) May we return to the question I was putting to you as to how far trade effluents can be dealt with upon land?—It seems to me, Sir, that unless in exceptional cases where the trade refuse is of such a kind as to be antiseptic to the germs which purify the sewage or where it is injurious to vegetation it can be dealt with quite as well upon land as ordinary sewage can. There are very numerous cases in the West Riding, as you are aware, Sir, where the trade refuse is acid in re-action, where it may contain phenol compounds, and such sewages as these do interfere with the treatment of the sewage upon the land. There is another common class of case where the trade refuse contains a large amount of fatty matter which is very difficult of destruction, very indestructible; and wool washing refuse, if that is turned on to land, almost immediately clogs up the surface of the land.

6320. Then speaking generally trade refuse and trade effluents which would interfere with land treatment would also interfere with artificial filtration?—Certainly, and I think in all those cases or the majority of them if the trade refuse has removed from it all those objectionable matters, for instance, if the wool washing refuse has the fat removed from it, it can be mixed with the sewage and dealt with quite well upon the land or in any other way.

6321. Then it would be a wise course for local authorities to take to call upon manufacturers first of all to settle the solids from their effluent before turning them into the sewers, would it not?—It would be very wise, Sir, and a very necessary course. There is a considerable number of sewage works in the West Riding the results of which are interfered with because of trade refuse, because the manufacturers are not asked to remove from their trade refuse these deleterious matters. On the other hand it is the tendency in the West Riding I should say now in manufacturing districts to allow the manufacturers to discharge their trade refuse into the sewers if they will undertake to put it through some preliminary treatment before joining their drains up to the sewers.

6322. With the view to settle solids?—With the view to settle solids.

6323. Or removing grease?—And removing grease. I have here several conditions drawn up by sanitary authorities. The first is a paper which I read at the Sanitary Institute at Leeds in 1897.

6324. Give us generally the character and conditions?

6325. (*Mr. Power.*) Do the manufacturers accept the obligation put upon them?—In most cases, Sir, they are glad to do so; they recognise that it is right, I believe, and they have fallen in with the requirements of the sanitary authorities in most cases.

6326. (*Colonel Harding.*) And the alternative if they do not so fall in is that they would have to treat their effluents wholly themselves?—Much more thoroughly.

6327. Whereas in this way a rough partial treatment is all that is asked of them?—That is exactly the position, Sir.

6328. May I ask, in passing, the settlement of these solids has been found in some cases to be almost profitable to the manufacturer, has it not—in some cases?—Oh, yes, it has indeed. In many cases what they recover is profitable to them.

6329. For instance in the case of coal, I believe, that has been distinctly proved to be so?—That has been very profitable.

6330. And I think in the paper trade also advantage has been found?—In certain instances in the paper trade and the woollen trade such preliminary treatment as we are now speaking of has been found profitable, because a great deal of fibrous material can be recovered and the wool washing grease can be recovered, and the soap from the scouring of the goods can be recovered.

6331. Then subject to such preliminary treatment by manufacturers and the withdrawal of matters which interfere with the treatment of the sewage you think, from your point of view, representing a Rivers Board, that it is better that the treatment of trade effluents should be by the local authority rather than by the individual manufacturer?—I think, sir, in such places as the West Riding, where the manufacturers are so numerous and they are placed so close together on the streams and often on small streams, that no very good effect, no nearly perfect result at least, will be got in the purification of the rivers until that course is followed, because in a district say—there are several of our districts—where there are thirty large trade pollutions, if each manufacturer has purification works of his own, and a District Council has its own sewage works, it would be practically impossible to ensure that all these works are working well at the same time; there will always be a proportion of them—that is my experience—that will be unsatisfactory. It may be temporarily or it may be constantly, but some will be unsatisfactory, and then the discharging of polluting refuse from one of these mills may suffice to spoil the results of the purification obtained at the other places. On the other hand, sir, there is a very important question arises in that connection. On the small streams where the water is used by all the manufacturers for condensing, it will be impossible to allow the manufacturers to discharge all their waters into the sewers, otherwise there would be no stream left. In many cases it would be interfering with the riparian rights. But in such cases, sir, I do not know if it affects what you are dealing with to-day, it is my strong opinion that in such cases there should be a grouping together of the manufacturers; there may be a group of six or eight or ten manufacturers who would very economically and much more effectively purify their refuse together at one joint works than if each of them had separate works, and I have tried my best in several cases to persuade the manufacturers to combine in establishing trade refuse purification works, but I have been unsuccessful in every case.

6332. (*Mr. Power.*) You would combine different trades in a group?—They would have to be selected trades; some kinds of trade refuse would not combine well, but on the whole it would be better if different trades were separately grouped.

6333. (*Major-General Carey.*) It would be next to impossible to get them to amalgamate voluntarily?—I have found it impossible.

6334. Because one of these works might do the whole mischief?—Yes.

6335. (*Mr. Killick.*) Do you find any practical way of

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dealing with fellmongers' effluent?—Land treatment has given us the best results in those that we have got effectively purified.

6336. They require so much land that that is a case where it is almost compulsory to treat them by the authority?—Yes, land treatment alone is no good for fellmongers' refuse, but land treatment after the removal of the suspended solids, and of course in a crowded locality where the land cannot be obtained it is almost necessary that the authority should deal with it. Tanneries refuse is in the same category.

6337. (*Chairman.*) If you had a separate system of sewers for trade refuse, how would you get them to divide?—A separate system of sewers?

6338. Did you not say in some cases you thought it would be desirable to have separate sewers for trade refuse?—They would be separate sewers so far that certain groups of manufacturers would be dealt with; their trade refuse would be taken to one place and dealt with all together, so that they would be really separate sewers.

6339. Would your view be that the manufacturers should have to provide that sewer for themselves?—I do not think, sir, it will ever be obtained unless by the action of Parliament; as General Carey has said it will never be obtained voluntarily.

6340. But on whom ought the cost to fall—the manufacturers or the district?—It would require to be considered in this way: in districts where the sanitary authority was dealing with the bulk of the trade refuse, in these districts there might be certain groups where it would be impossible for them to receive the trade refuse into their sewers. In such cases I think the sanitary authority might be at the expense so as not to put one set of their manufacturers in a better position than the others, but speaking generally if the sanitary authority was not dealing with any of the trade refuse, in that district then I think it should fall upon the manufacturers. But that is a question, sir, if you will allow me to suggest, the Commission should carefully consider. It affects the West Riding very materially indeed, and I think some kind of arrangement of this sort might be attained, that the sanitary authorities should deal with the trade refuse in their districts on certain conditions, conditions which might include the provision of preliminary treatment to remove the deleterious matters, and which also might include the demand of an extra rate of some kind from the manufacturers. I believe many of the manufacturers would be glad to do that; they have expressed that view to me.

6341. (*Colonel Harding.*) I am afraid I led you away from the answer you were going to give. If you could briefly give us the headings of one or two of these regulations?—I have here regulations adopted by the Borough of Keighley, by the Urban District of Liversedge, and by the City of Leeds for the preliminary treatment of trade refuse before they are prepared to receive it into the public sewers. It may suffice, sir, if I run through those drawn up by the Borough of Keighley, and I should say that in Keighley all the manufacturers have complied, or are carrying out works to comply with these conditions, and are connecting up to the sewers.

6342. (*Mr. Power.*) All of them?—All of them. The first is as to volume, that is, the volume is to be reduced as far as possible by keeping condensing water and surface water out of the drains. The second is that all trade waste waters except suds are to be passed through coke filters on the downward and upward principle. The third is as to the treatment of suds, that suds shall in all cases be treated for the removal of grease, and they have added to that since this was drawn up that the effluent from the soak plant for the removal of the grease is to be filtered before it is passed into the sewers.

6343. One moment, then; the several methods of treatment—are they to obtain the approval of the Sanitary Authority?—These are conditions drawn up by the Sanitary Authority, and given to their manufacturers.

6344. They say do this, but the exact method that they shall adopt, is that subject to the approval of the Sanitary Authority?—No, it is left to themselves; but practically in Keighley it is approved by the Sanitary Authority, because the work has been left in the hands of the borough engineer.

6345. There is uniformity, then, of method in each particular instance?—Practically, in this case. The time of discharging is to be regulated by the Corporation, that all the trade waste waters shall not discharge into the sewers at the same time. "A manhole or other opening shall be provided to the satisfaction of the Corporation on the line of drain between the mill and the Corporation sewer, and the officers of the Corporation shall have the right to take samples at this point, and to inspect the tanks, at any reasonable time. Before commencing any works for the treatment of trade waste waters plans shall be submitted to the Corporation for their approval. In the event of any of the foregoing conditions and regulations not being complied with the liberty to discharge trade effluents into the Corporation sewers shall be *ipso facto* suspended." There are many other districts in the West Riding where similar regulations have been drawn up and are being carried out.

6346. (*Colonel Harding.*) Then I take it that these regulations are really only practicable where a town has a special water supply, and where the manufacturer does not draw directly from the stream?—Or in other cases where the water used by the manufacturers may be drawn from a large stream and discharged into the same stream again through the Sanitary Authority's sewage works before anybody is affected by the loss of the water.

6347. Then where such arrangements can be made between the Local Authority and the manufacturers to secure the partial treatment of sewage, what is aimed at is not complete purification, of course; the effluents passing into the sewers are to a certain extent objectionable?—Oh, certainly.

6348. But you get final results, after treatment by the Local Authority, much better than you would get if you were merely doing it with the individual manufacturer?—Much better.

6349. So that, speaking generally, you favour that arrangement?—Certainly; what is aimed at, I think, is merely the removal of deleterious matters from the trade refuse.

6350. (*Mr. Killick.*) You are of opinion that such an arrangement is better both for the manufacturers and for the authorities?—I am looking at it, sir, from the point of view of the river only; it is very much better for the river, and certainly very much better for the manufacturer.

6351. (*Colonel Harding.*) It is better for the Rivers Board?—Much better for the Rivers Board.

6352. The detail of their supervision to deal with the Local Authority, and not with the 50 manufacturers?—That is so, sir.

6353. Just one question more. I was speaking to you about the possible nuisance arising from the treatment of sewage upon sewage farms. Do you not think that the admixture of trade refuse to some extent reduces the probability of nuisance, partly by dilution and partly the introduction it may be of antiseptic matters into the sewage—that the introduction of trade effluents into a sewage to some extent reduces the probability of nuisance arising in the treatment of such sewage?—It does, sir.

6354. Have you not been struck, for instance, in noticing the large volume of sewage at Leeds, with the comparatively small nuisance that arises in connection with its treatment, even in the old-fashioned way?—It depends entirely upon the nature of the trade refuse. In cases where there is a large mixture of refuse from dye works that is so, but in cases, on the other hand, where you have a large admixture of refuse from breweries and tanneries, it is quite the opposite; the nuisance is very much increased. There are several sewage works in the West Riding where the refuse from breweries and tanneries is mixed with domestic sewage without proper preliminary treatment, and where nuisance does arise.

6355. (*Chairman.*) Well, now, can you give us the worst case of that going on to land?—I think probably from a brewery the worst case is in Lemonroyd, in Rothwell Urban District, where the brewery refuse is in excess of the domestic sewage.

6356. And that goes on the land?—It is treated chemically through tanks, and then goes on to land.

6357. And does that cause any nuisance on the land?—Yes.

6358. It does?—It is very offensive.

6359. (*Mr. Power.*) After the chemical precipitation?—After the chemical precipitation.

6360. (*Chairman.*) And does the land purify it ulti-

mately?—No; the effluent is very frequently unsatisfactory.

6361. And is it suitable land?—It is suitable land. I do not think the area of land is sufficient for the amount of mixed trade refuse and sewage.

6362. (*Mr. Power.*) But in that instance the brewery refuse is in volume in excess of the sewage?—In excess of the sewage.

6363. Considerably in excess?—I should say considerably in excess; I have not the figures by me, but I should say it is considerably in excess. There is another case in Queensbury Urban District, and complaints have been made from time to time of the smells arising from the sewage works, which the Sanitary Authority, at least, put down to the brewery refuse mixed with their sewage, and in that case the sewage is treated by chemical precipitation, and passed on to land areas, and the effluent is usually satisfactory. They have a much larger area of land in proportion in that case.

6364. (*Chairman.*) And the land purifies that?—It purifies it.

6365. (*Colonel Harding.*) Then does the nuisance arise from the solid deposit in the tanks?—I think, so far as I can gather, the nuisance arises from the putrefaction of the sewage in the settling tanks.

6366. (*Chairman.*) In both cases?—In both cases chiefly. In the Lemonroyd case it also arises because the land gets sewage sick, and the tank effluent is ponded up on the surface of the land and putrefies there.

6367. There is a nuisance really on the land itself?—There is a nuisance really on the land itself.

6368. (*Colonel Harding.*) Due to the too small area?—Due to the too small area.

6369. (*Chairman.*) What size is that farm?—I think my Lord, the best instance of that to be obtained anywhere is at Burton-on-Trent, where they have a very large area, and where there is still an unsatisfactory state of matters.

6370. (*Major-General Carey.*) Where there is a very large volume of brewery refuse?—Where there is a very large volume of brewery refuse. Lichfield is another place where they have a very large volume of brewery refuse, and where they have a bad state of affairs by land treatment, but now are dealing with the refuse by filtration through coal, and producing a remarkably good effluent. I find, sir, the land area I can give you is perhaps a little misleading; there are practically two sewage works at Lemonroyd in the Rothwell Urban District; on one of them the sewage is purely domestic; they adjoin one another, and the effluent from that portion is usually satisfactory. On the other the bulk of the sewage is from the brewery, and the effluent is generally, or very frequently, unsatisfactory, and a nuisance does arise; but I have the acreage all in one figure; there is a population,—the number of houses drained to those two sewage works is 1,708; the total area of land is 20 acres, 18 of which are available for sewage treatment.

6371. (*Chairman.*) Then do the two kinds of sewage go on to the land together?—There is an admixture, yes.

6372. There are two different sewage works, but the effluent from both goes on to the same land. Is that it?—The areas of land adjoin, but the brewery refuse is discharged into a public sewer receiving sewage from one part of the district, and discharging into one set of tanks the mixed brewery refuse and house sewage. The bulk of the house sewage discharges into another set of tanks and goes on to another set of areas of land.

6373. Oh, I see, then the 20 acres takes both?—Takes both.

6374. But you do not exactly know how they are divided?—I cannot give it you now; I have only the two together here, I find.

6375. (*Major-General Carey.*) Where the conditions of a sewage farm are satisfactory both as regards area and character of subsoil, would you consider that good management was absolutely necessary to success?—Oh, certainly.

6376. After all, on it really depends whether the effluent is satisfactory or not?—Certainly good management is half the battle. Even with a bad sewage farm good management can produce remarkable results.

6377. But the land can recover itself with certain intervals of rest?—Certainly.

6378. Have you had sufficient experience of biological filters to say what is the result of mismanagement?—From the experience I have had of them it seems to me very probable that if biological filters are put into the hands of the ordinary sewage farm manager they will from time to time be misused, as sewage farms have been, and if they are misused they will get sewage sick, and will not recover themselves nearly so easily as land areas. In fact, they get clogged up, and will have to be renewed entirely.

6779. And that would be a very costly business?—A very costly operation.

6380. Owing to the quantity of material required?—Another point from my own aspect of the question, if bacterial filters are misused they immediately give a bad effluent; if land is misused, it does not necessarily mean that you get a bad effluent, but rather more it means that the land becomes clogged up, and ceases to give the effluent; the sewage will not pass through it.

6381. Still the sewage could be put upon that land, whereas the filters, the moment they become clogged, would become useless?—Well, the land too, if it became clogged, would not allow the sewage to pass through it.

6382. (*Chairman.*) Have you any experience of sewage which goes into tidal rivers or the sea?—None of the sewage goes into the sea in the West Riding, and in the case of the tidal rivers our direct pollutions are very small, compared with the pollutions that come down from above. All our large towns and populous districts are inland, and their sewage is discharged into inland waters and carried down into the tidal reaches.

6383. Then you would not care to speak much upon that point?—No, my lord, no, beyond what I have said I have no direct experience. I have, of course, in other posts had to do with the discharge of sewage both into the sea and into tidal rivers. One case lately I have had to go into, the discharge of the sewage of Dumfries and Maxwelltown, in Scotland, into the River Nith, water-closet sewage with all the excreta and some trade refuse as well, and the results there were very bad indeed.

6384. (*Major-General Carey.*) Was the sewage discharged in that case on the ebb tide or at all times?—At all times, at the very highest point to which the tide ran.

6385. Then in that case the sewage would be always in a state of oscillation on the flood and ebb, and practically never leaving the place?—That was found to be so from various experiments, and the solids were greatly deposited in banks and in the bed of the stream. I might instance, sir, one case I know where the sewage of Sunderland discharging into the sea certainly comes back to some extent, and the solids are deposited on the shore. That, I fancy would be found to be the case in a great many seaside places.

6386. (*Mr. Power.*) That is crude sewage?—That is crude sewage.

6387. (*Major-General Carey.*) That would not happen if the sewage were discharged on the strongest part of the ebb and the current carried it right away from the place?—It would depend entirely upon the direction and force of that current.

6388. (*Mr. Power.*) But is it discharged into the sea or into the Wear?—The bulk of it is discharged into the sea; some, I have no doubt is discharged into the Wear.

6389. (*Colonel Harding.*) Perhaps the Chairman would allow me, if we have finished with the question of land treatment, to take the opportunity of asking Dr. Wilson whether, as far as he knows, there are any important experiments or works being carried on in the West Riding connected with artificial filtration, beyond those at Leeds, that should receive our attention. I think Sheffield is doing a good deal in that way?—Sheffield has had for a considerable time some contact beds dealing with a fairly large volume of their sewage.

6390. Will you tell us from the analyses you have made what are the results which have been obtained at Sheffield?—The results have been very good indeed; the effluent from the biological treatment of the Sheffield sewage is one of the best we have had, and consistently good, but I am unable to say as to the length of life of the filters at Sheffield.

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6391. They have not, I think, taken any careful observations?—They have no careful enough observations.

6392. But beyond Leeds and Sheffield, have you within your area any important works on artificial filters that should receive our attention?—I think not, sir; there are a great many, but they are all small, and I do not think you could learn any more from them than you could learn at Leeds and Manchester.

6393. Just one point as to Morley; I think at Morley they tried continuous filtration of their sewage, which contains a great amount of greasy matter, and I understand they failed?—It was an utter failure.

6394. Can you tell us anything about that failure and how it came about, and how the experiment was carried out?—They carried it out, sir—the apparatus was Whittaker and Bryant's.

6395. Was it a coarse filter?—It was of coarse material.

6396. And was the sewage poured by means of a sprinkler?—And pumped by a pulsometer.

6397. What was it they put upon the filter?—They had an open septic tank, I think of a capacity equal to a day's flow of the sewage passing through it; they pumped the effluent from that by a pulsometer, and distributed it by a sprinkler on the top of the filter.

6398. Now give us the story?—The effluent was almost uniformly bad. We had once or twice samples taken, and I saw it once or twice, and the district inspector reported it several times, and I may say it was almost uniformly bad.

6399. And did they work it at a proper speed of flow?—I believe so. I believe they were advised in the matter by Whittaker and Bryant; I understood so.

6400. What did you ascribe the failure to in that particular case?—I think entirely to the kind of sewage. They found, for instance, that the septic tank sludged up very rapidly. In Morley the bulk of the manufacturers are already connected up to the public sewers, and most of them discharge all of their trade refuse without any preliminary treatment, solids, grease, impurities of all kinds, directly into the sewers, with a very large amount of fibre. You are aware, sir, that at Morley the bulk of the trade is that of shoddy manufacture, and from that a large amount of fibrous matter is discharged with the trade refuse. These matters sludged up the open septic tank very rapidly indeed.

6401. But how did that act on the filter?—The filter did not give good results, I think, probably because so many solids went through upon it, and perhaps also because some of these kinds of trade refuse may have had an antiseptic effect, but they had no definite experiments, no series of analyses made to show anything of that kind.

6402. In fact, there are no scientific data in regard to that experiment to guide us?—I am afraid not, sir, beyond the general fact.

6403. Beyond the fact that it failed?—That is so.

6404. (*Major-General Carey.*) What is Bradford doing, do you know?—Bradford at present is constructing a set of settling tanks. They have constructed a set to deal with—I forget the figures at present—with a small proportion of their sewage, and they are going on constructing their tanks. They have also been carrying out some experiments; they have, for instance, at present an open septic tank running into a small coal filter, and they have tried some experiments in different methods of precipitation, but the bulk of the Bradford sewage, sir, is discharged into the streams untreated.

6405. They have not arrived at a satisfactory solution?—Oh, no, they have not.

6406. Was it not found at the Bradford sewage works that the filtration process following upon their chemical treatment was not effective—produced very little improvement in the effluent?—At times, sir, at times according to the precipitant they were using they produced an acid tank effluent, and of course the tank effluent, being acid, was scarcely capable of improvement by filtration.

6407. And it was found in fact that it was not so improved?—Not much improved, but at other times, when they were using another kind of precipitant, and not producing an acid effluent, there was a distinct improvement.

6408. It is possible the same causes were at work at Morley as at Bradford?—Quite so; something may have been in the sewage which had an antiseptic effect. I should add that Bradford Corporation are to have a Bill in Parliament this year for the acquisition of a large site—the same as they went for before.

6409. (*Major-General Carey.*) That they consider absolutely necessary for the purification of their sewage?—Yes.

6410. (*Mr. Power.*) I should like to go into the question of the amount of sewage that may be expected at the outfall works: you were telling us that the newer works at the West Riding are constructed to deal with six times the dry weather flow?—That is so.

6411. And that the weir on the outfall came into operation when the sewage was diluted with five times the dry weather flow of storm water?—Yes.

6412. Could you get any record as to how much sewage and storm water flowed over the weir during the whole 24 hours, and how many hours it overflowed continuously—I am afraid there is no such record available, sir, as far as I know. I could obtain it by setting inspectors to watch by the permission of the sanitary authority.

6413. It would have to overflow during the whole 24 hours, would it not, to get down to the works six times volume of the dry weather flow?—Quite so.

6414. If you could get the number of hours during which in any 24 hours the weir overflowed, we might obtain in that way an indication of the probable amount that came down?—To get any reliable information on that point, sir, a very detailed and accurate series of measurements would have to be made. In the first place the fixing of these storm overflows is theoretical.

6415. I am speaking of the outfall of the newer class of sewers now?—Even of the newer works it is theoretical, and the actual flow would have to be gauged for a considerable time before you would be able to say that six times the dry weather flow was coming down in the sewers. Even the dry weather flow in this case is theoretical; it is taken as an estimate usually upon the population.

6416. That is the point; you mean the dry weather flow is generally an estimate, and upon that estimate the capacity of the sewer is determined and the overflow weir is fixed?—That is so. As a general thing I should say the actual dry weather flow does not correspond very generally with the estimated.

6417. Is it less or more?—Sometimes less, sometimes more; in cases where old sewers are left in, generally more, because of subsoil getting into the sewers. In cases where the subsoil water is rigidly kept out of the sewers it is probably less, because as a rule, I think, there is not that amount of water from a public water supply used which is generally credited.

6418. Which is estimated?—Yes, which is estimated. I do not think it is probably worth your while listening to it, but I did, as I promised, put together some Tables with regard to the sewage works in the West Riding and the acreage per thousand persons; but I must confess I have been myself unable to draw any very definite conclusions from them, so that probably it would not be worth while.

6419. (*Colonel Harding.*) You do not think that any general answer of a useful character can be given to the question?—The whole thing is so complicated, and there are so few scientific observations on the matter that I feel myself unable to express any opinion.

6420. All you could do would be to say that in certain cases good results are obtained from land treatment working at certain rates of gallons per acre?—I could only give you that in certain cases good results are obtained and in certain cases bad results.

6421. Have you any typical case you would like to bring before us?—I do not think so; I do not think it would serve any useful purpose, sir. I got out the information. I have all those Tables here. What I proposed doing if you had requested it was to put in these Tables and to state that, for instance, in the case of broad irrigation I have given six farms with the kind of soil, the population, the dry weather flow, as nearly as I can get it, and a general statement of the results, that they are generally satisfactory, then give the area for a thousand persons, and to say that the smallest area giving a satisfactory result is such and such a figure.

6422. I suggest, Lord Iddesleigh, that it would be useful for the tables to be put in.—

6423. (*Chairman.*) Yes; I should think they might

be?—I have found, sir, if I may say so, a difficulty in dividing the soils. It seems to me to be pretty difficult to say what is loam and what is clay, and the other varieties of soils; I have done them as accurately as I could. That sample is a very typical instance of to be met with in the West Riding; I have a very great number of farms of that kind.

(*Colonel Harding.*) It seems to me a number of sections of typical soils would be very useful.

BROAD IRRIGATION AFTER CHEMICAL PRECIPITATION.

ACREAGE used for SEWAGE TREATMENT.

Name.	Area in Acres.	Soil.	Population.	Dry Weather Flow.	Results.	Area per 1,000 Persons.
				Gallons.		
Ben Rhydding, Ilkley	6	Alluvial silt	1,000 with w.c.'s	—	Generally satisfactory	6 acres.
Rawdon	12	„ „	3,077	50,000		3¾ „
Sedbergh	4	Sand and gravel	1,500 with w.c.'s	30,000		2½ „
Wrenthorpe, Stanley	4	Loam on clay subsoil	5,670	90 000		¾ an acre.
Wortley Rural (Ecclesfield)	3½	„ „	4,000	60,000		⅞ of an acre.
Soap House Lane, Woodhouse	4¾	Clay	2,900	34,800	Generally unsatisfactory	1½ acres.
Soap House Lane, Woodhouse. Mill	1½	„	1,250	15,000		1 acre.
Handsworth	2	„	1,175	14,100		1½ acres.
Elsecar, Hoyland Nether	11	„	13,000	—		¾ of an acre.
Ravensthorpe	6¾	Sand and gravel	5,500	160,000		1 acre.
Hemsworth	3	Clay	2,445	—		1 „
Kinsley, Hemsworth Rural	2¼	„	860	—		2½ acres.
Great Houghton, Hemsworth Rural	1½	„	555	—		2½ „
Kippax, Tadcaster Rural	4	Loam on clay subsoil	2,796	13,000		1½ „

INTERMITTENT FILTRATION AFTER CHEMICAL PRECIPITATION.

ACREAGE used for SEWAGE TREATMENT.

Name.	Area in Acres.	Soil.	Population.	Dry Weather Flow.	Results.	Area per 1,000 Persons.
				Gallons.		
The Fall, Ardsley, East and West	4	Loam on clay subsoil	1,900	36,430	Generally satisfactory	2 acres.
Lemonroyd, Rothwell	18	Alluvial	8,540	—		2 „
Thornhill	7	„	8,500 with w.c.'s	200,000		3 roods.
Thurlstone	6	Loam on clay	2,000	80,000		3 acres.
Hoyle Mill, Ardsley	1	Alluvial	1,000	3,500	Generally unsatisfactory.	1 acre.

BROAD IRRIGATION AFTER CHEMICAL PRECIPITATION AND FILTRATION.

ACREAGE used for SEWAGE TREATMENT.

Name.	Area in Acres.	Soil.	Population.	Dry Weather Flow.	Results.	Area per 1,000 Persons.
				Gallons.		
Thornton	2	Loam on clay	4,000	120,000	Generally satisfactory	½ acre.
Conisbro', Doncaster Rural	2½	„	9,280	855,000		¼ „
Canklow, Rotherham Rural	1½	Deposited soil on clay subsoil.	1,200	24,360		1¼ „
Rawmarsh	8	Clay	13,340 with w.c.'s	250,000	Generally unsatisfactory.	½ „

Dr. H. Mcl. Wilson, M.D., B.Sc.

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BROAD IRRIGATION—ARABLE LAND.

ACREAGE USED for SEWAGE TREATMENT.

Name.	Area in Acres.	Soil.	Population.	Dry Weather Flow.	Results.	Area per 1000 Persons.
				Gallons.		
Doncaster (Sandall)	237	Sandy soil and subsoil.	32,000 with w.c.'s	640,000	Generally satisfactory	7½ acres.
Dewsbury	73	Sandy alluvium with gravelly subsoil.	30,000 with w.c.'s	1,250,000		2½ ,,
Balby	10	Loam	2,300	–		4½ ,,
Gisburn, Bowland Rural	4	Sandy soil, gravelly subsoil.	444 with w.c.'s	3,000		9½ ,,
Smalley Bight, Stanley	12	Alluvial soil	8,000	160,000		1½ ,,
Knaresborough	10	Alluvial soil	4,649	–		2 ,,
Barnsley	55	Alluvial soil and clay	40,000 with w.c.'s	1,250,000	Generally unsatisfactory	1¼ ,,
Castleford	11	Loam upon stiff clay subsoil.	16,250	300,000		½ ,,
Mirfield	25	Alluvium upon clay subsoil.	10,000 with w.c.'s	150,000		2½ ,,
Skipton (with trade refuse)	50	Loam	12,000 with w.c.'s	–		4 ,,
Acomb, Great Ouseburn	9	Alluvium upon clay subsoil.	2,181 with w.c.'s	34,000		4 ,,

BROAD IRRIGATION—PASTURE LAND.

ACREAGE USED for SEWAGE TREATMENT.

Name.	Area in Acres.	Soil.	Population.	Dry Weather Flow.	Results.	Area per 1000 Persons.
				Gallons.		
Giggleswick, Settle Rural	3½	Sandy soil, gravelly subsoil.	786	23,580	Generally satisfactory	4½ acres.
Settle	5	Sandy soil, gravelly subsoil.	3,066	480,000		1½ ,,
Doncaster (low pasture)	100	Sandy and peaty	4,000 with w.c.'s	80,000		25 ,,
Cleckheaton (Scholes)	9	Loam upon clay subsoil.	1,700	30,474		5½ ,,
Oatlands, Knaresboro Rural	11	Loam upon clay subsoil.	1,125 with w.c's	22,500		9¾ ,,
Dent, Sedbergh Rural	3	Alluvium upon gravelly subsoil.	283	1,250		10½ ,,
High Bentham, Settle Rural	5	Alluvium upon gravelly subsoil.	550	–		9 ,,
Wetherby Rural	20	Alluvium upon gravelly subsoil.	2,000	–		10 ,,
Greasboro	3½	Loam upon clay subsoil.	2,900	–	Generally unsatisfactory	1 acre.
Harrogate (chiefly pasture)	293	Loam upon clay subsoil.	20,000 with w.c.'s.	800,000		14½ acres.

INTERMITTENT FILTRATION.

ACREAGE USED for SEWAGE TREATMENT.

Name.	Area in Acres.	Soil.	Population.	Dry Weather Flow.	Results.	Area per 1000 Persons.
				Gallons.		
Addingham, Shipton Rural	4	Alluvium upon gravelly subsoil.	2,500	–	Generally satisfactory	1½ acres.
Horbury	11½	,, ,,	6,500 with w.c.'s	136,000		1⅝ ,,
Keighley (trade refuse, chiefly *inter. fil.*).	40	,, ,,	25,000	780,000		1½ ,,
Ripon	8½	,, ,,	9,000 with w.c.'s	300,000		1 ,,
Pateley Bridge	4	,, ,,	3,000	–		1¼ ,,
Low Bentham, Settle Rural	1½	,, ,,	596	20,000		2½ ,,
Ingleton, Settle Rural	3	,, ,,	1,033	40,000		2¾ ,,
Gargrave, Skipton Rural	4	,, ,,	1,296	–		3 ,,
Oakworth	2½	,, ,,	2,500 with w.c.'s	318,744		1 ,,
Idle, Bradford	8	Loam upon clay subsoil.	3,800	–	Generally unsatisfactory	2 ,,
Glusburn, Skipton Rural	5	Alluvial silt	1,942	–		2½ ,,
Burley	6	,,	2,661	–		2¼ ,,
Heckmondwike	28½	Loam upon clay subsoil.	11,000 with w.c.'s	350,000		2½ ,,
Earby, Skipton Rural	3	,, ,,	3,050	–		1 ,,

Mr. GEORGE CHATTERTON, called; and Examined.

6424. (*Chairman.*) I think I have the pleasure of speaking to Mr. Chatterton; you are a member of the Institution of Civil Engineers?—I am.

6425. Would you give us your opinion as to whether lands of all kinds when used alone and without the artificial addition of chalk, cinders or other material, will properly purify domestic sewage?—I should say no; I should say that peaty, boggy land—all land so situated that the level of the subsoil water is near the surface—that is to say very near the surface, will not properly purify domestic sewage.

6426. Now may I ask you a question; what is your definition of broad irrigation?—Broad irrigation is where the sewage is brought down in an entirely untreated manner without any tanks whatsoever, the solids and all go over, and the farmer or the sewage manager spreads that over the surface of the land as well as he can get it over it, and he goes about from plot to plot, that is to say he does not use the whole of his land one day, he uses only a very small proportion of it. By putting as much of the sewage over the surface of the land as he is able to do by his distributing carriers.

6427. How would you distinguish between broad irrigation and intermittent filtration?—I say the line of demarcation depends upon the nature of the soil; you cannot help a sewage getting through a very porous soil, and in that way the line of demarcation between broad irrigation and filtration is not very distinct.

6428. The difference is not very great?—It is not very great.

6429. (*Major-General Carey.*) But if the land without filtration is laid out in plots, would it not take out a much larger quantity?—It would undoubtedly, because the surface is laid out better.

6430. I am assuming it is laid out in plots and underdrained?—I am very much afraid of underdrains myself.

6431. Even when the land is prepared in plots?—I am very much afraid of putting sewage directly over an underdrain; but you must have sufficient underdrains, so as to keep the level of the subsoil water down, and to keep your land always sweet.

6432. (*Chairman.*) What kinds of land would you consider unsuitable for intermittent filtration?—Any clay soil or any stiff impervious clay, and certainly of course, as I have mentioned before, the peaty boggy soils.

6433. Could you mention any case where you found clay land unsuitable?—Yes; there is a place not very far from London—Wimbledon—which originally was a stiff clay, and there was an attempt made to turn that into a downward intermittent filtration area, and I have no doubt Mr. Willis has got the plans of the Local Government Board 1876 Report, the Rawlinson and Read report, and he will see plans No. 13 and 14; they give the most elaborate system in which that land was laid out. The result of it was an absolute failure. The sewage went over the surface of the clay and went straight down through. There was a trench cut, probably 6ft. deep, and about 2ft. 6in. to 3ft. wide at the top, and in the bottom of that was laid the subpipe for carrying off the effluent. It was then filled up with burned ballast. The result of it was that the sewage flowed over the surface, went down this trench into the subsoil drain, and came out—well, when I saw it on many an occasion it was worse than when it went down almost, and the result of it was that the present farm bailiff did not take up the drains, but he dug down alongside of them, and he put an impervious band of clay all round, so that the sewage could not reach them directly. That is the system in operation now; that is, for the old portion of the land, but on the portions of the land that have been acquired since 1876 there are no underdrains whatsoever, except under a road, and all the trouble has been—it has been got over now for the last 20 years nearly, but the original trouble was all on account of not being able to prevent what was practically crude sewage going into the underdrains. I may say that I know a good many other clay farms where they have tried to underdrain, and they have been invariably unsuccessful. In my practice I would not do it for anything.

6434. Would a clay land be equally unsuitable for sewage which had been allowed to settle and where the solids had deposited themselves?—I think that if you deposit the solids either by mechanical means—that is, by simple subsidence, mechanical subsidence in a considerably sized tank, I think that makes a very great deal of difference and renders the application of the sewage to the land far more suitable. *Mr. G. Chatterton.* 14 Nov. 1900.

6435. Far more suitable?—Far more suitable; and I would go so far as this, that I think it ought to be done in every case.

6436. That the solids should be taken out somehow?—Somehow.

6437. Either by tanks or by screens?—Well, I am not a great believer in screens.

6438. In screens?—No, I am not.

6439. Then do you believe in tanks?—I believe in tanks, but where you have tanks it is far better, in my opinion, to use a small proportion of chemicals, and you get your precipitation so much more rapidly and so much better than if you have mechanical subsidence on a continuous system through tanks; in the latter case the tank becomes an open septic tank after a short time, and it becomes in the summer time in my own experience a most objectionable nuisance.

6440. You would say that an open septic tank was a nuisance?—Undoubtedly.

6441. In your own experience?—In my own experience. I had to deal with a place where, in order to get rid of the sewage while my sludge presses were being put down, I had to pass the sewage through the tank, and I had no means of cleaning the sludge out. Of course, if you have your tanks, say, in three rows, in triplicate, and use the same endeavours to take out your sludge as you would after chemical precipitation, that mitigates the nuisance; but in that particular case it was a most undoubted nuisance, and my authority very nearly suffered severely from it.

6442. Was that a case where the sewage was purely domestic?—Purely domestic. There was undoubtedly a great reduction in the sludge.

6443. From the mere fact?—It forms first of all, you see, when the sewage is passing through. You see, it must come up to the top, and gradually it forms a scum, and it forms a scum first at the entrance where the sewage comes in, and that scum gradually goes away right down, and that causes a nuisance—an undoubted nuisance.

6444. And that scum formed all over the tank, did it?—In this case it did not form quite down to the end of the tank except on one occasion, because we never let it run long enough.

6445. Did you remove the scum from time to time?—We did, yes. We were threatened by the neighbours, and we had to make an effort. It was very difficult.

6446. Have you ever had any experience of a closed septic tank?—No, no personal experience; I have seen them, but I have never put one up myself.

6447. And you could not say that if this tank, which was objectionable when it was open, had had a roof over it, it would have been objectionable or not?—I should think it would not.

6448. You think it would not?—Certainly not.

6449. And as to the quantity of the sludge that disappeared or seemed to disappear in the septic tank, have you any idea of the amount?—I have not been able to estimate that.

6450. You have not?—No.

6451. And would you say that precipitation tended to increase the amount of the sludge?—Undoubtedly.

6452. It does?—Yes.

6453. Therefore, if it was a mere question of getting rid of the sludge, it would be better not to have any chemical precipitation at all?—It would. I have at the present moment recommended for an urban district council—I prepared two schemes for them, one a septic tank and filters—bacteria beds, and the other chemical treatment and bacteria beds, and I have strongly recommended the former—the septic tank. It is both cheaper, and, I believe, more efficacious; but that is a small place.

6454. Is it domestic sewage only?—Purely domestic.

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6455. And would you be inclined to make the same recommendation for domestic sewage mixed with trade refuse?—I have not had a great deal of personal experience in trade refuse. The only trade refuse that I have had personal experience in is brewery refuse, which I consider should be treated at the breweries, and the Bradford sewage, which largely consists of wool combers refuse. I have spent a great deal of time on the latter; it ought hardly to be called sewage at all it is an entirely different substance.

6456. Might I ask you to let us know what you recommend about storm water?—First of all there is a question of necessary safety valves. I say they are necessary as safety valves, and if you can fix your storm overflow, that is, so fix it and so be able to adjust it—I do not mean a movable storm overflow—so that you are dealing with six times the average dry weather flow, I think that there are very few places that you could not put the remainder into. And, of course, it depends altogether on how the system has been carried out. You are bound to have storm overflows almost anywhere. I have recently constructed a scheme—a very large scheme—and I have not put in any storm overflows. I know where I can put one in if it is wanted, but it will not be wanted. But the reason of that is that they started on maiden ground. There were surface water drains but no sewers. The authority on my recommendation borrowed £10,000 from the Local Government Board to make the house connections themselves, and in every case we made the connection. We have brought it up to the curtilage of the house, and then, when the actual work of connecting it has been carried out, and it is being carried out under plans submitted to the local authority, and very carefully inspected, so far as I know there never will be any necessity for a storm overflow there unless something unforeseen occurs. The sewers themselves are watertight, and there is nothing coming in but sewage and storm water from the backs of the roofs of the houses and the curtilage of the yard.

6457. Then storm water will not get into the sewers?—It will not get in, but in places where storm water does get in it is in very variable quantities, with the very best system of separation. Now at this place at times after a very heavy thunderstorm you will certainly get 12 to 14 times the average dry weather rate of flow, and in the old towns—take an old town, an old Kentish town that has been drained for, say, 30 to 40 years—you will get a discharge of storm water equal to 20 times the average rate of flow, and then the sewers are not able to take it; and then in a great number of those old towns the sewers are down at such a level that you cannot put in a storm overflow because you cannot get it into the river; but I say for ordinary towns and ordinary storms that if you deal with six times and treat six times the average volume of domestic sewage, you will be doing well.

6458. That is to say, you would not recommend any storm overflow coming into operation until the flow was about six times the ordinary?—I think not. Of course, under those conditions I do not think that the whole of the six volumes should be treated in the same way that the dry weather sewage is; I think there should be separate provision to deal with it so as to turn it on to a specially prepared filter—to turn a portion of it anyhow.

6459. Even when it was only six times the amount?—Yes.

6460. Then you would bring your storm overflow into action as soon as the flow reached six times the normal rate?—Yes. I think if you arrange your weirs—and for this purpose the dry weather sewage should be gauged—so that you will receive at your work six volumes, and supposing that you are getting down ten volumes, then the other four volumes would go away over your weir untreated. I think that is inevitable almost in the greater number of places, but when you get your six volumes down to your works then the treatment of these six volumes is a different thing from treating the ordinary average dry weather flow.

6461. But suppose you have a tank and the whole of the six times the flow would have to go into the tank?—Yes, and we are tanks designed for that purpose. Putting six times the volume through at any time will not have any detrimental effect whatsoever; it only means going through a little faster. Of course, we never use the whole of our tanks at one time, and it may happen that during a few hours a tank that is meant for the dry weather flow of, say, the next day or something like that comes into use, because the man in charge has to turn the sewage through it in order to lessen the velocity. For tanks I say it is no detriment; that is, if the tanks are designed of a capacity of not less than 50 per cent. of the daily dry weather flow, and if it be possible—and the place can afford it—I would very much prefer to make the ordinary tanks as much as 75 per cent., that is, the total capacity 75 per cent. of the daily dry weather flow.

6462. Going back to land, have you any experience of artificial preparation of land by the addition of chalk or cinders or anything of that sort?—Yes, I know that if you have properly screened town refuse, not town refuse that has been burned in a destructor, not that at all, but where you have the place properly scavenged, and the refuse brought into heaps, sifted, burned and sifted again, I say that you can increase the purifying capacity of a clay soil or an indifferent soil very largely indeed—probably more than double it. By putting this carefully on the surface you raise the whole surface to start with, and undoubtedly it has a most beneficial effect

6463. And would that beneficial effect be lasting do you consider or would the land tend to revert?—It depends on what the soil is. I am talking now of putting it on to a fairly stiff clay and keeping on until you build the land up, but it is a process that can only be done by a thoroughly experienced man who will see that he burns his stuff properly, and does not put on any garbage or muck or anything like that. It is a process that must be done carefully. Also on the same principle an ordinary domestic sewage sludge which has been pressed; when it comes out of the press is in a very useless condition, but if it is thoroughly dried and then powdered up, that also has a considerable beneficial effect on the land provided it has not been done too much. You could not put nearly so much of that on the land as you could of well-sifted house refuse.

6464. Do you mean when you say put it on to the land, simply lay it over the surface?—Lay it over the surface.

6465. Not dig it in?—Dig it in slightly.

6466. And that is an operation that would have to be repeated, I suppose?—It is continuously repeated, and it is most beneficial; you can grow excellent crops of ryegrass; altogether the appearance of the farm would be a great deal better; but also it is a thing that must be done by a man who is experienced and thoroughly understands it.

6467. And do you consider that the question of crops is important; does land purify better with crops growing on it?—Well, I think so. Of course, I am not a farmer, but all the farmers that I have ever talked to undoubtedly say so, and I think a sewage farm without crops would be a misnomer. Of course you have not the whole of your land cropped.

6468. Could you tell us from experience of your own with sewage farms whether the sewage is absent from a large part of the farm generally?—Yes.

6469. It is only a comparatively small part of the farm that is under sewage at a time?—I should say a fourth or a fifth part—one-fifth probably.

6470. And do you consider that the land deteriorates by constant use?—No, I do not. I have been very interested in that. I think a farm properly laid out in the first instance, supposing the land is good, will go on regardless of time.

6471. Many years?—Yes, and always be sweet and healthy, and I also know that where I have seen land that was once a good bit of loam but had been disgracefully neglected and covered with a slime of sewage sludge probably half an inch or an inch thick, that in excavating that, and in digging out a few spadefuls, that probably four or five or six inches below the surface you could take the soil in your hand and find it perfectly clear and perfectly sweet. I have noticed that nearly every bad sewage farm that I have had to visit, was all right underneath but bad on the top.

6472. Would you say that the management of a sewage farm required special knowledge or that an ordinary farmer could manage it?—Special knowledge.

6473. I think you told us that you had not had very much experience with trade refuse?—No, I have not; I mentioned all the experience I have had.

6474. In regard to the sea or tidal waters, have you had any experience there?—Oh, yes.

6475. You have?—I was with Sir Joseph Bazelgette as one of his assistant engineers 25 years ago. We carried

out the Torquay main drainage, and I was his assistant engineer there, and I was also on the West Kent, under Sir Joseph Bazelgette and Mr. Alfred Williams, a member of the Institution. That was about 22 years ago. And I also carried out works at Devonport and Stonehouse with Sir Joseph Bazelgette, and on my own account I have recently carried out—it has been completed now for some eight or nine years—the largest sea outfall in Wales, the Rhondda Valley outfall, and I have given the whole thing very great attention.

6476. Do you know of any case where letting sewage go into the sea or into tidal waters has created a nuisance or has been injurious to health?—Yes, I do. I cannot say very much about injurious to health, because you are outside the province of an engineer when you come to deal with health. I may mention that I am at the present moment carrying out the main drainage of Dublin for the Corporation, and the Registrar-General of Dublin says there are no unhealthy effects from the stinking condition of the river Liffey, which is merely an open sewer from Kingsbridge down to Ringsend, but I think that sea outfalls require a great deal more consideration than they probably received 30 years ago or 25 years ago. It was then considered almost good enough to put in sewage untreated anywhere where you could get salt water or into any tidal water without a proper investigation of what was going to become of it. I think that that is why in several places—I do not like to mention their names—you certainly do see unpleasant sewage particles floating about near very desirable neighbourhoods. But for a place like Margate, which has a first-rate outfall, a place like Torquay, where the outfall is at a place called Hopes Nose, where the flood tide sets one way and the ebb sets another, in both directions out to sea, and under no conditions whatsoever could it go into Torquay, and it has been proved that it cannot—to purify the sewage is unnecessary. But there are other places where sufficient consideration has not been given. I know that things are much more strict now than they were then. A few years ago I was engaged by the riparian owners to oppose the Corporation of Exeter putting their sewage into the tidal part of the River Exe, and that was rejected very properly, I think, by General Carey's Board. That is the sort of thing, I believe, that used to be done, and anything in the way of tidal water was good enough. Now the Rhondda Valley scheme goes down into about 30ft. deep of water—40ft. at a high spring tide—and goes down one mile from the foreshore, and discharges into the tidal estuary of the Bristol Channel. I have tried to trace it very often, but I cannot see anything of it after 100 yards or so. I have never heard any complaints from Cardiff. Very grave complaints have been made against the western outfall at Cardiff, but the Cardiff people are trying to remedy that as fast as ever they can; the complaints are not so much about the outfall as about the discharge of the sewage, that is to say, it causes floodings. I would like to mention that to bear out what I was speaking about: and although Parliament may have sanctioned a sea outfall 20 years ago, or an outfall supposed to be into the sea, or into a tidal harbour, I might say this, that I disapprove altogether of crude sewage being put into what are called artificial tidal harbours—that is, tidal harbours that are formed by breakwaters and walls. There are two very important suburbs alongside of Dublin, and 25 years ago they got an Act of Parliament to discharge crude sewage into the tidal estuary—I will call it into the harbour—and the Dublin Corporation recently tried to annex them to bring them all in; the Dublin Corporation were defeated in that, but one of the great points was to know was this a proper outfall. The Dublin Corporation themselves are carrying out a scheme of precipitation and will discharge the sludge that they get in a similar manner to the way in which the London sludge is discharged, viz., by taking it out to sea. That is all sanctioned by the Local Government Board. Well, the Committee, although they rejected the application to annex the suburbs—this was a Committee of the House of Lords and the House of Commons, Sir Ughtred Kay-Shuttleworth in the chair, —gave the following as a part of their decision: "Your Committee have come to the unanimous conclusion that it would be a public advantage if there were one administration to control the drainage and sewers and treatment of the sewage of Dublin and the townships. They think that it would be absurd if one part of the sewage were treated at Pigeon House Fort" (that is the Dublin outfall) "and other parts discharged a little distance away within the seawalls of the bay without corresponding treatment. They are also of opinion that the whole community benefits by the great works now being carried out for purifying the Liffey, and they recommend that legislative steps should be taken to constitute a joint drainage board for the city and the townships of Rathmines and Pembroke, representing the Corporation and the two urban district councils, and to distribute over the entire the past and future burden of both systems of drainage."

6477. Have you ever happened to come across any case of danger from oysters or mussels or cockles or anything of that sort?—In Dublin Harbour, undoubtedly.

6478. And where harm has come from them?—Undoubtedly, Dublin Bay oysters are condemned, that is oysters that are taken somewhere else and laid down in Dublin Harbour; in fact, I think they are prohibited now, I will not say for the whole of Dublin Bay, but Dublin Harbour.

6479. (*Major-General Carey.*) There is one point about the overflows being adjusted. In answer to your question 18, if the overflow weir is adjustable at the discretion of the person in charge?—I did not mean that, General; I meant that you would adjust it to the actual flow and then fix it. It would be almost an impossible calculation to fix the weir when designing the works.

6480. You would have to calculate the flow, and then fix it permanently?—And then fix it permanently.

6481. I understand when you use the word "adjustable" I thought you would adjust it from time to time?—That an engineer and designer would not fix it, but leave it to be adjusted finally by the engineer in charge.

6482. You consider that good management is indispensable to the success of a sewage farm even when the conditions are perfectly satisfactory as to area and subsoil?—I do.

6483. Have you had any experience of bacterial filters?—I have.

6484. Do you consider that the same good management is essential?—I do; I think that it is more essential; I think that you require probably a more intelligent man than the ordinary sewage farmer, as I can see he has not got used to bacteria beds yet. I have two acres of bacteria beds that I constructed myself at the Croydon rural sewage works, and in addition to them we have a piece of land; there are about 22 acres of land in addition to these two acres, and we get most excellent results from the bacteria beds, but we have a very intelligent man; we have got a combined system of disposal there, and there is only the one staff to do the two; the manager puts as much as he can on the bacteria beds, and he adjusts that with what he can put on his farm, because it is a treble process, first of all chemical precipitation, then two acres of coke bacteria beds three feet deep, and then 22 acres of land. Everything must go through the tanks.

6485. You consider it an advantage that there should be land in addition to the filters?—I do, but at the same time I am bound to say that in the analyses we have got and which I have given in my evidence, from Dr. Thomas Stevenson of the Croydon rural sewage and effluent he reports that the effluent coming from my bacteria beds, after, of course, chemical treatment first, and then the bacteria beds, is fit to go into any stream from which drinking water is not immediately taken.

6486. That is in well-managed works?—Yes; we never have three fillings per diem.

6487. No, but in well-managed works?—Oh, thoroughly well-managed.

6488. If the filters are neglected do you consider you would get the same effluent or that the filters would go on working?—I think not. I could put those filters out of working order in a week almost; if I were to put the crude sewage on them I should.

6489. If there was any neglect in the mode of working filters you consider those filters would come to a standstill?—They would come to a standstill and I should get an indifferent effluent and probably get into trouble. Whatever effluent you get from beds like that it would not be right to trust to them entirely; you ought to have land.

6490. There is only one other point about the tidal outfall. Do you consider that sewage should be discharged on the ebb tide on a current which takes the sewage completely away from the town or river?—I would prefer to have a continuous discharge and to fix the outfall so that the sewage will be taken away on both tides. In some places the ebb tide will give you a far worse set of conditions than the flood.

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6491. I am assuming now that the ebb tide is carrying the sewage away from the place?—Yes, if the ebb tide is favourable.

6492. If the ebb tide is favourable?—And if the flood tide will take it into a dangerous place, that is to say near a bathing place or anything like that, or interfere or produce unpleasantness, sewage particles floating on the surface, I should say then the sewage should be diverted.

6493. It should be discharged on the ebb?—It should be discharged on the ebb.

6494. And does that apply particularly in the case of discharge into a tidal river?—On a small tidal river I am almost entirely against any sewage discharge—crude sewage—at all.

6495. You must discharge into some tidal rivers—take the Ouse for instance?—You must consider the size of the river, but there are many small rivers that are tidal into which you should not discharge crude sewage at all.

6496. You should treat the sewage on the land?—No. I should then take the solids out of it; take the suspended matter out; it would be quite enough.

6497. You would discharge only treated sewage?—Quite so.

6498. Would you discharge then at all times of the tide?—No.

6499. Or on the ebb tide?—On the ebb tide. But I would like to say this about the question of discharging sewage for a particular period of the tide only, say six hours; when you consider that you would probably be asked not to discharge the storm water, that is the six volumes, but have to store that for six hours out of twelve you will run your storage tanks up to such an enormous cost that there are very few towns able to stand it. In bathing towns, small places, it becomes a tremendous question when you have got to store your storm water, that is your six volumes and sometimes more, in some cases you would require to only discharge for three hours out of the twelve, and in others two, and that, of course, makes it a very large question.

6500. Do you consider that crude sewage should under any circumstances be screened before discharge into the sea?—I think it is such a simple matter to take the very coarse matters out.

6501. By screening?—Yes, very simple by screening. Of course there is a difficulty about that if you have an outfall going through private land. It must go through private land in most cases going down to the sea; I think it could be done in a public roadway without difficulty, but if you want to make a screen half the size of this room—a movable screen, I do not think that you can do that, so far as I know, under the Public Health Act, and you probably would have to go for compulsory powers to purchase that little bit of land; anyway, I have been met with that difficulty. Now if you go to purchase a bit of land half the size of this room from a landowner for the purpose of a sewage screen, he will defeat you to a dead certainty, so if you have to screen crude sewage, I think that the Local Government Board ought to take into consideration what facilities it can give to local authorities for acquiring the necessary space. It could be a covered up arrangement, and need never be seen by anybody, and need certainly be no nuisance, but the sentimental objection to it by the landowner would in my opinion be often sufficient to defeat any scheme.

6502. Where sewage effluent has to pass over oyster beds or shell fish beds, do you consider that thorough treatment is necessary?—Well, I should prefer not to have the oysters there at all or where the effluent could possibly get near them. I do; I consider the most thorough treatment is necessary. I had to report on competitive schemes on the River Colne, and although it was almost physically impossible that the effluent could ever get from the outfall to the oyster beds, I reported that the effluent should be of the very highest quality that could be made, that is, it should have chemical treatment first, then it should be treated by bacteria beds, and then over land so as to get the very highest quality of effluent that a chemist knows. And that was adopted, and then I am sorry to say the place was turned into an Urban District, and the Council adopted a much cheaper scheme with nothing like that treatment at all, and I am told that scheme has been sanctioned and carried out. I would object to it strongly.

6503. You said that there is a nuisance from the scum on the open septic tank: is that nuisance caused when the scum is perfectly still and quiet?—I could not say that. It was perfectly quiet for a certain distance, but my tanks were too big for open septic tanks, and therefore the scum had not properly formed, I should say, over the whole of them, but what did form was quite enough; there was a most abominable stench.

6504. Arising from the scum?—Arising from the scum, and it was observable a considerable distance, and in fact so much so that the neighbouring Medical Officer of Health came to our Medical Officer of Health and complained and threatened us with all sorts of proceedings; and he was perfectly right. I had three months of this experience of running crude untreated sewage through an open tank, and I hope I shall never have it again.

6505. (*Colonel Harding.*) In answer to question No. 2, Mr. Chatterton, you say that you do not approve of putting crude sewage on land, except where the land is satisfactorily situated in regard to isolation. I gather, therefore, that you in such cases anticipate nuisance?—Yes; I think there is more or less a nuisance in all such cases.

6506. Well, but you anticipate nuisance especially from putting crude sewage including solids in suspension upon the land?—I do.

6507. But would not that nuisance be reduced very much if the area were adequate, if you only precipitated upon the land a thin film of solids instead of allowing a thick accumulation?—There would be a nuisance unless you have a very large area, and unless the land is thoroughly isolated; but whatever nuisance you have then would be confined to the land itself.

6508. May I take it that you believe the nuisance would be reduced by having a sufficiently large area?—Yes.

6509. But precipitate only a thin coating of scum?—In my own practice now, wherever I can I arrest the solids by an upward filter.

6510. I am just now considering the case where all that the sewage contains is put upon the land?—Yes.

6511. I understand that in broad irrigation a very large area is required, probably for that reason, is it not?—Quite so.

6512. That the land may be used so as to only take a small covering?—It can be so used.

6513. Of these solids?—Yes.

6514. And in that case the solids are more rapidly reduced than if you let them accumulate, say, to a depth of several inches?—Oh, yes; undoubtedly the larger the area the easier it is to work a broad irrigation farm.

6515. And that is probably the definition of the term broad irrigation?—Very likely. The larger the land and the better the distribution the less the scum.

6516. Have you had any experience of the difference in nuisance arising from the treatment of purely domestic sewage and domestic sewage mixed with trade effluents?—Only at Bradford.

6517. Where, of course, the character is so special that we cannot argue very much from it?—Yes. With regard to brewery refuse, I have had a place I was concerned with where they had brewery refuse; it was a most intolerance nuisance.

6518. But apart from brewery refuse, domestic sewage itself is perhaps most likely to cause nuisance?—I think brewery refuse would beat it.

6519. (*Chairman.*) You said, did you not, brewery refuse you think should be treated by itself?—Brewery refuse mixed with sewage, that is for irrigation purposes, seems almost to beat any sewage farmer.

6520. (*Colonel Harding.*) You suggested that brewery refuse should be treated at the brewery?—I think it should be.

6521. Are you able to suggest to us any kind of treatment applicable to brewery refuse at the brewery?—I think it might be treated with lime and alumina and the sludge pressed. There is a gentleman who I think was before you—he has had more experience in this matter than I have—Mr. Santo Crimp; what was undoubtedly an abominable nuisance at Shepton Mallet, has been by means of the works that he carried out and the works which are down at Shepton Mallet brewery itself turned into a success.

6522. You have no experience of your own?—No.

6523. I was rather interested in what you told us about the experiments you made with septic tanks; I gathered that you had found the particular septic tank with which you had experimented to be a perfect nui-

sance?—I had three tanks, and I tried to get one of them cleaned out to avoid that nuisance.

6524. But you told us a serious nuisance had arisen?—Undoubtedly.

6525. And you told us you had recommended septic tanks followed by filtration in another case?—Covered septic tank.

6526. You believe in the covered septic tank?—I have not put them down myself, but in a small place of 6,000 inhabitants I am going to use a septic tank without much pumping; I can get rid of the sludge and I think I have got plenty of land in addition. I would not use it without that. I have land for filters, and probably 25 acres of good land in addition.

6527. As to the nuisance that arises in the case that you mentioned to us, what was the capacity of your septic tanks, approximately?—Yes, open septic tanks they were.

6528. If you would tell me relatively to the flow of sewage that would be sufficient; did they contain a day's supply?—The three of them contain 75 per cent. of the daily dry weather flow.

The three of them together would contain three-fourths of a day's flow?—Seventy-five per cent. of a day's flow.

6530. But surely in such case full septic conditions would not have time to arise?—I do not suppose they had; as I say, the scum was not down to the very end of the tank, but it would be for half the tank.

6531. Do I understand you to say the sludge was not to the bottom?—Yes; the scum did not extend down to what I call the far end of the tank.

6532. It did not cover the whole of the surface?—Not the whole; I do not think so.

6533. What made you think it was the scum?—I was there every day.

6534. After the scum was removed, was there no stink?—Not when we treated it with chemicals.

6535. Do not let us go away from the septic experiment: you said something about the scum causing a nuisance and you removed the scum?—Yes.

6536. Did the nuisance disappear with the scum?—When I say we removed the scum, we were never able to remove the whole of it.

6537. When you removed the scum there was a development of gas?—When we removed the scum the nuisance was to a great extent abated.

6538. Did not the development of gas go on?—We then used permanganate.

6539. The experiment was not continued?—No.

6540. Nothing can be concluded from that?—No, only as to this black scum that rose to the top of the tank; at that time there was not such a thing as an open septic tank in existence that I know of.

6541. Then this was domestic sewage?—It was purely domestic sewage. It was a makeshift; we had to get rid of the suspended matter.

6542. You have no experience of open septic tanks carried out on a large scale with sewage mixed with trade effluent?—I have not.

6543. In this case an open septic tank with purely domestic sewage led to a nuisance?—Yes, as far as my experience went.

6544. You explained that a covered septic tank would remove the nuisance?—Yes.

6545. Can you explain to us how and why?—The nuisance is probably due to the production of malodorous gases, is it not?—I have seen the covered septic tank and I have never smelt anything like what I have heard the smell described as—I am not going to say that a covered septic tank is as clean a thing as could possibly be, because I have heard other engineers say that they have smelt them at a distance, but my own experience is not to that effect; no, I cannot explain it.

6546. In what way would the enclosing of the tank help you, for if malodorous gases are produced by the putrefaction of matters in the tank, these malodorous gases cannot be confined indefinitely in the tank; they must escape somewhere?—That is a question that I could not answer.

6547. I think you told us about having superintended an experiment with bacteria beds to the extent of two acres?—It is not an experiment, it is an actual work; we treat half the sewage there.

6548. You have personal experience of working bacteria beds extending to two acres?—Yes.

6549. And you have told us the results were satisfactory?—Yes, very satisfactory indeed. The land is too small there; I had to adopt some other system.

6550. Was that worked with double beds working in succession?—No, those very tanks that we have been talking about are used for chemical precipitation by which I take the suspended matter out.

6551. But in regard to the bacteria beds themselves, did they work in pairs one following another?—No; when I say one following another it did not come out of one bed and into another bed.

6552. Each bed worked independently?—Each bed was three feet deep, and the effluent had got to be pumped out of the bed.

6553. On account of the levels?—On account of the levels—it is dead flat—and the effluent is then pumped on to the land.

6554. This work consisted, therefore, of single filtration of effluent from chemical precipitation?—There are two acres of the beds, and they are all divided up into different compartments.

6555. For single filtration?—For single filtration.

6556. And the results obtained were satisfactory?—Absolutely.

6557. Can you give us any typical analysis; give us the oxygen absorbed in four hours, permanganate, that would do?—This is an instance: oxygen required to oxidise the organic matter, ·091 grains per gallon.

6558. And in your own opinion the result was satisfactory in regard to effluent?—Oh, undoubtedly.

6559. Have you taken at any time any note of the effect of the action of those beds upon the reduction in the capacity of the beds?—No, I have not been able to experiment upon that. I myself have not been able to gauge it, but both the man who does the pumping and the man who does the cleaning tell me they cannot notice anything appreciable; do not notice anything.

6560. That is effluent containing very little solids in suspension?—Oh, very little.

6561. Almost clear effluent?—Oh, yes, almost clear effluent, and I attribute the whole success to that effluent.

6562. To the thorough preliminary precipitation?—Yes.

6563. Where is this work?—Croydon Rural Sanitary Authority at Merton.

6564. It may be seen there at any time?—Oh, yes.

6565. Now, in regard to the storm waters treated upon land, if an area of land is proposed to be used not only for the dry weather flow, but for several dilutions of such dry weather flow, the area of land would have to be calculated, would it not, upon a maximum flow, including dilution?—Well, I would prefer to have something separate for a portion of the dilution, so as not to interfere with the regular farming operation.

6566. Let me put it in another way: If an area of land is calculated to deal with the dry weather flow and to utilise at one time say one-fourth or one-fifth only of the area of the land to deal off such area with storm waters would dislocate the whole thing?—It would.

6567. So you must therefore have an area of land originally calculated upon the total flow of the dilutions or you must have an area of land specially set apart for the treatment of storm waters?—I think so.

6568. (*Mr. Killick.*) In cases of towns such as Chester, on the Dee; Warrington, on the Mersey; or Preston, on the Ribble, would you recommend that the sewage be thoroughly treated before the effluent was turned into the tidal waters?—I do not think it would require it at Preston.

6569. You do not think it would require it?—No, I think not, if the solids were taken out and the sewage taken down some distance. I understand in the Ribble there is a most enormous dilution. It is the solids that give all the trouble; in my estimation the suspended matter goes to the bottom. I do not think that the organic matter in solution after the solids have been taken out, where the dilution of tidal water is very great, does any harm.

6570. Would you say the same of Warrington?—I am not sufficiently acquainted with the tidal volume there.

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6571. In Chester?—I should say Chester ought to be thoroughly treated as well as I recollect; I should say that they ought to have a second treatment, anyhow a bacterial treatment. I should say that Chester, if it had a chemical treatment and a bacterial treatment, and got anything like these results that we have got here, would never give rise to any complaint.

6572. Of course, the results there are sewages that are almost as good as many effluents?—Well, of course, this is crude sewage; you see it is a dilute sewage at the Croydon Rural Sewage Works.

6573. From?—The subsoil water at times; it rises up and it comes through. I did not construct the sewers; they were constructed by another engineer, and the house drains were constructed without any great supervision, I think, not by the engineer who constructed the main pipes, and I do not think they were put in with very great care, and the result of it is that when the springs rise in the gravel we get a flow there, probably 60 to 70 gallons a head, and that accounts for it.

6574. Really your position is this, that where the tidal estuary is so large as it is on the Ribble at Preston, you do not think that it is necessary to do more than take out the solids?—I do not.

6575. But where the tidal estuary is of the proportion of the Dee at Chester, then you think a full treatment?—I would not like to be very positive about that, but I think it is small. I may say in Dublin the tidal estuary is very large, and I would not think for one moment of giving it a further treatment than taking out the solids. There was some very remarkable evidence given at that inquiry.

6576. (*Colonel Harding.*) But are there any works to be seen?—There are no works to be seen yet except sewers in the ground. The evidence in regard to the extraordinary manner in which the solids discharged from the 250,000 Dublin population behaved as they went down the river given by Dr. Adeney and Mr. Letts, of Belfast, was very interesting.

TWENTY-SIXTH DAY.

Thursday, 15th November, 1900.

PRESENT:

The EARL OF IDDESLEIGH (*Chairman*), *presiding.*

Sir MICHAEL FOSTER, M.P., F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY.
Colonel THOMAS WALTER HARDING.
Mr. THOMAS WILLIAM KILLICK.
Mr. WILLIAM HENRY POWER, F.R.S.

Mr. F. J. WILLIS, *Secretary.*

Mr. R. A. TATTON, recalled; and Further Examined.

Mr. R. A. Tatton. 15 Nov. 1900.

6577. (*Chairman.*) You are the Chief Inspector of the Mersey and Irwell River Boards?—I am.

6578. You have a table to hand into the Commission?—I have. It is as follows:—

APPROXIMATE AREAS required under varying conditions: Arable land.

		Direct to Land. 2 (a).		After Precipitation or mechanical settlement. 5 (a), I. and II.		After Filtration on Bacteria Beds. 5 (a), III. and IV.	
		Ratio of Population per Acre.	Acres per 1,000 Persons.	Ratio of Population per Acre.	Acres per 1,000 Persons.	Ratio of Population per Acre.	Acres per 1,000 Persons.
Broad Irrigation.	Gravel	100	10	500	2	1,000	1
	Light Loam	100	10	500	2	750	1⅓
	Heavy Loam	75	13⅓	200	5	400	2½
	Chalk	—	—	—	—	—	—
	Peat	Unsuitable.	—	Unsuitable.		Unsuitable.	
	Clay	50	20	100	10	300	3⅓
		2 (b).		5 (b), I. and II.		5 (b), III. and IV.	
Intermittent Filtration.	Gravel	150	6⅔	500	2	1,000	1
	Light Loam	150	6⅔	500	2	1,000	1
	Heavy Loam	75	13⅓	300	3⅓	500	2
	Chalk	—	—	—	—	—	—
	Peat	75	13⅓	200	5	400	2½
	Clay	Unsuitable.		Unsuitable.		Unsuitable.	

6579. Will you give us your opinion whether land of all kinds, when used alone and without the artificial addition of chalk, cinders, or other material, will properly purify domestic sewage?—I am of opinion that land of all kinds will purify domestic sewage.

6580. Should you say land of heavy clay would purify sewage?—Yes, it will; but you must have a large area of the land, and you must use it on the broad irrigation principle, and allow the sewage to flow over the surface, as a small quantity only will filter through.

6581. Well, now would you mind defining what you call broad irrigation?—I should define it roughly that if land is used for broad irrigation you have no drains; it is not drained at all. If it is used for intermittent filtration it is drained. The line is rather an ill-defined one between the two systems, but that is, generally speaking, the accepted definition.

6582. With a heavy clay would not the sewage pour over it; would it filter through heavy clay at all or might you not have such heavy clay that the sewage would not penetrate it in any degree?—Yes, it would; it would be almost entirely surface action. The sewage would flow over the surface of the land, and would be purified as it flows over the vegetation. The actual percolation through the soil is very slight indeed.

6583. Then what would cause the purification there—the vegetation on the top of the clay?—Yes. The organic matter in the sewage would be deposited on the land—on the surface of the land—and taken up by the vegetation.

6584. How would the areas given in your table be affected, if at all, by allowing the storm sewage up to six or eight times the normal flow to be treated on the land; by variations in the volume of dry weather flow, the organic matter remaining constant?—The areas given would not be affected in the cases of light land by allowing storm sewage up to six or eight times the normal to flow on to the land, as they are calculated on the assumption that the flood water is dealt with; but in the case of clay land, where the treatment is on the surface, an additional area would be required, as the land would be thrown out of operation after the flood for a longer period than light land. The additional area necessary would probably amount to 50 per cent. If the daily volume of the dry weather flow varies, the organic matter remaining constant, the estimate for land area must be based on the maximum volume.

6585. What area of each kind of land is required for 1,000 persons assuming a dry weather flow of 30,000 gallons a day: (*a*) for broad irrigation; (*b*) for intermittent filtration when the sewage is first (1) allowed to settle mechanically, the solids not going on the land; (2) chemically precipitated and then allowed to settle, the solids not going on the land; (3) chemically precipitated and then filtered; (4) subjected to treatment in bacteria beds?—If the solids are prevented from going on to the land there is probably little difference, from the point of view of its effect upon the land between mechanical settlement and chemical precipitation provided that the chemicals used do not retard biological action, but as the solids will not settle as rapidly without chemicals as with them, tanks used for mechanical settlement should have a larger capacity; we may therefore class 1 and 2 alike. (1 and 2) If the land is of good quality it should deal with a population of 500 per acre after the solids are removed, either by broad irrigation or by intermittent filtration. This is the ratio at Wilmslow (northern outfall), population 2,500, and at other small places on the Mersey and Irwell watershed. At Eccles, population 35,000, where the land is heavy loam, somewhat lightened by ashpit refuse and underdrained, the ratio is also 500 per acre, the sewage being previously mechanically settled; the results are satisfactory, but owing to the rapidity with which storm water reaches the works a dilution of 6 to 1, at which the storm overflow is fixed, is soon reached and much storm water goes away untreated. (3 and 4.) The answer to this question depends upon the efficiency of the precipitation and filtration processes; if they are efficient and the effluent from the filters or bacteria beds is of such a character that the organic matter left in it is insufficient to cause it to putrify there will be little left for the land to do, and the factor of how much water the land will pass will be the important one giving due regard to intervals of rest. If, on the other hand, the purification effected by the filters or beds is only partial the remainder of the work will have to be done by the land and the area required will be in proportion to what has to be done.

6586. What kind and quantity of chemicals give the best results?—The chemicals chiefly used as precipitants are lime, lime and sulphate of iron, alumino ferric, the latter also sometimes used in conjunction with lime; which of these is the most suitable is a chemical question, and can only be ascertained by experiment on the particular sewage to be treated; the manager of a sewage works, if he is a man of intelligence, will soon ascertain what suits his particular case best. When the sewage contains manufacturing waste it will vary considerably from hour to hour, and great attention will be required in adapting the chemicals to suit it. In these cases it is often an advantage to use two chemicals, such as lime and sulphate of iron, one being an alkali and the other an acid.

6587. What information can you give as to the size, kind, and mode of use of settling tanks or filters which give the best results?—On the question as to the size of purification tanks I am strongly of opinion that a great advantage is to be gained by having the tanks of large capacity; the advantage quite outweighs the extra cost entailed in their construction. They should have a capacity of not less than the volume of the dry weather flow in 24 hours, and twice this capacity if six times the volume is dealt with, and should be constructed so that they may be used either on the quiescent or continuous flow system. During dry weather probably not more than a third of the tanks will be in use, but after a flush of rain some of the extra tanks will be used to receive the first of the storm water, which may require subjecting to special treatment, the later storm water being treated in the remaining tanks on the continuous flow system. If the tanks are of insufficient capacity great disturbance is caused by storm water which will not only itself be insufficiently precipitated, but if allowed to flow quickly through tanks in which the ordinary sewage has been treated will tend to carry forward precipitated sludge, much to the detriment of the filters or land on which it is subsequently treated. On the Mersey and Irwell watershed there are over thirty local authorities using filters at their outfall works. They are composed of sand, sand and polarite, magnetite, coke, cinders, and coke and cinders combined. Some are used by themselves, others are assisted by land; the volume of sewage deal with varies from 45 gallons to 1,200 gallons to the square yard, and in some cases is held up in the filter, in others passed rapidly through it. Success depends upon proper construction, on the fitering material being of good quality and clean, on the distribution of the sewage being regular, in the case of rapid filters on the means of washing them being efficient and frequently used, in the case of biological filters on the volume of the sewage turned on to them not being too great and the mineral solids being intercepted, and in all cases on the management being efficient. Instances can be given where each kind of filter has failed and where each kind has been successful, but it is impossible to say which has been proved to give the best results or that one kind has been proved to be a failure or another kind a success. Mechanical means have lately been introduced with good results, for distributing the sewage by means of sprinklers. It is claimed that under this system the filter may be used continuously for long periods.

6588. Now, have you got any opinion as to this; do you believe that filtration is chiefly mechanical—that is to say, that a sewage that is passed through some materials equally fine gets purified irrespective of what the materials consists of?—It is very hard to answer that question. My opinion is that in a great measure it is mechanical in the first instance, that your filtering material removes the organic matter, but the cleaning of that material is biological no doubt—that is to say, when the organic matter is once retained in the material of the filter it has to be removed again from that material by biological action; but I answer that question with great diffidence, because I am not a biologist, but an engineer.

6589. When sewage is going over the land, do you advise that there should be some kind of preliminary treatment, or would you let the raw sewage go on the land?—If you have preliminary treatment, if you remove the solid matter, you do not require so large an area of land. In that way it is advantageous, and also if you run raw sewage on to land it may possibly cause a nuisance. In hot summer weather it is more likely to cause a nuisance if the solid matter flows on to the land, and has to be treated on the surface, than if it has previously been settled in tanks.

6590. In most cases you would be disposed to think that the preliminary treatment for getting rid of the solids was a good thing?—Yes, I think it is.

6591. Is there any particular way in which you prefer getting rid of the solids? I mean to say, would you screen them, or would you let them go into a settling tank?—I should let them go into a settling tank, and either treat them by precipitation with chemicals or ordinary subsidence.

6592. Would you treat them with chemicals too, or would you simply let them go into a settling tank?—If your tanks are of large capacity you can save the cost of chemicals: you can let the sewage pass through the tanks, and the solid matter settles out; on the other hand, if your tanks are not of large capacity, you must use chemicals in order to get the solid matter out more quickly.

6593. Have you any experience with these large tanks?—Yes, I have; I have got several works in operation on the Mersey and Irwell watershed, where there are large tanks in operation.

6594. And where solids are allowed to settle?—Yes, in some cases they are allowed to settle, in some cases they are precipitated with chemicals. I have instances of both kinds.

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6595. You consider those tanks are satisfactory; at least you consider that they are desirable?—I consider they are a great assistance, certainly.

6596. And do you know what happens to the sewage while it is in those tanks. Take the case of a tank first of all where there has been no preliminary treatment, do you know whether the solids in the tank diminish while they are in the tank?—No, I cannot tell you from my own experience. I know the results as regards that which they have got at Manchester.

6597. You do not know from your own experience?—No, I do not know.

6598. And in the same way you could not say where they have been treated chemically?—Whether there is any reduction in the solids?

6599. Yes, in the solids, or whether the solids have in any way increased?—If they are treated chemically, no doubt the solids increase, because, in addition to the solids in the sewage, you have the chemicals to remove.

6600. As regards the question of nuisance, do you consider a settling tank is likely to cause a nuisance?—No, it should not do so if it is properly managed.

6601. How near might it be to a dwelling, say?—Well, on sewage works you often have dwellings quite close to the settling tanks; for instance, the manager of the works and the men usually live very near; I do not know that they suffer in any way from it, but I should not personally care to have a house close to a sewage works, but that may be prejudice.

6602. Do you know any cases where there is a bad smell from these settling tanks?—Yes, in the summer I have noticed smell from a large area of settling tanks.

6603. Have you had any experience of open tanks and close?—A very few closed. I have three small places where they have closed septic tanks.

6604. And do you know whether there is any difference in the question of nuisance between open and closed?—With the closed septic tanks you are more apt to have a nuisance from the filters, as the septic effluent flows from the tanks it smells strongly sometimes. But the tank itself being closed up, no smell comes from that except through the outlet through which the water flows.

6605. Of course, if the smell is there it does not signify which place it is. It is a nuisance anyhow?—Yes, it is; it is very difficult to avoid, I think, any smell at all.

6606. Have you any experience of attempts towards artificially prepared land by the addition of chalk or cinders or other material or digging out the top soil and burning it and replacing it?—At Eccles they have done a certain amount in that direction; they have dug ashpit refuse into the land; it is a heavy loam, with beneficial results, and I know at Wimbledon they have turned the clay there into burnt ballast. Of course, you can do that; you can burn the clay, but it is an expensive process; that can be done.

6607. I only want to ask you where you have actually seen and known the process?—Yes, quite so.

6608. But you have known it?—Yes, I have.

6609. That, I suppose, increases the capacity of the land for filtration?—It does somewhat, no doubt. I have had no experience as to digging it in in heavy clay. I should doubt whether that would be a success permanently.

6610. Can you give any opinion as to whether the results of such a process are permanent, or only temporary?—At Eccles they are constantly digging in the ash-pit refuse.

6611. They would have to go on doing so?—I think so.

6612. Have you any opinion as to how frost and snow would affect purification?—Very hard frost will affect purification on clay land. I remember one hard winter some years ago at Tyldesley there was a great depth of ice, something like 9 inches in some places on the surface of the land; it was heavy clay land, and the water simply flowed over the surface, but in ordinary winters I think that no trouble is found as regards frost. The temperature of the sewage itself usually keeps either the filter beds or the land open.

6613. You do not think it is a very important question?—No, I do not think it is.

6614. Then do you consider that the cropping of the land effects its power?—I think it is an assistance so long as you use the right crops. I think the best of all is rye grass. It absorbs a large amount of moisture, and you get very heavy crops from it; you can get five or six crops of it in the year off the land. Potatoes or corn should not be sown at all.

6615. Because it prevents the sewage being applied to the land at all for so long, I suppose?—Quite so, during the summer months, which is the most important time to purify the sewage properly, they are not able to turn the sewage on to those crops because it would spoil them. In many places they use willows—put down willow beds, but I do not much like willow beds myself, because when they grow up they keep the air from the soil, and make the proper supervision of the surface a difficult matter, so that weak places caused by settlement or by rats, moles, etc., are difficult to detect.

6616. Do you imagine that the growth of willows really helps the land to purify?—There is no doubt that willows absorb a large amount of moisture, but I would very much rather have no willows at all, it is so important to let the air get to thoroughly aerate the surface of the land; it is of far greater importance than the absorption of water.

6617. Would you rather have a grass field?—I would rather have ryegrass than anything else.

6618. Now, speaking from your own experience of sewage farms, would you say that the length of time that the land has been at work has any effect on it, or that if it is properly managed it can go on indefinitely?—If it is properly managed and the land is not overdone with sewage it can go on, I think, indefinitely. We have had farms that have been in operation from ten to fourteen years. Very often one hears that a farm is done, is no use any longer, but in every case it is because too much sewage has been turned on to it, or because the farm has been badly managed. The population increases, and they go on sending the sewage to the same farm, and the result is that it turns sick, as they say, and will not treat the sewage properly, but if you keep to a moderate amount of sewage on the land I do not see any reason why it should not act indefinitely.

6619. Go on indefinitely?—Yes, I think so.

6620. What number of sewage farms have you knowledge of?—I have got 29 outfalls where land is used, on the Mersey and Irwell watershed.

6621. Twenty-nine?—Twenty-nine, I think, where land is used either with precipitation and land filtration, or with subsidence and land filtration, or with broad irrigation.

6622. Twenty-nine where they use land?—Twenty-nine where they use land in one form or another.

6623. Do you know in those 29 farms in how many cases the effluent comes up to the Mersey and Irwell standard?—I have the percentages here. It is worked out in rather a different way. Of the precipitation and land filtration outfalls for domestic sewage only, 84 per cent. of the samples come within our limit; of those using land with subsidence 89 per cent. come within our limit. Under broad irrigation 14 farms to which domestic sewage only is taken 82 per cent. come within our limit, and the three farms where sewage mixed with trade refuse is taken 42 per cent. come within our limits. That is to say that, roughly speaking, the results obtained by the mixed sewage are only half as good as those obtained with domestic sewage.

6624. I suppose that in any case the filtration, whether it is of land or whether it is through artificial medium, great care is required?—Oh, yes, that is of vital importance in any case.

6625. In any system?—Good management is of the greatest importance in any system, and the want of it always leads to failure. Local authorities are often slow to recognise this part, and loath to give the wages necessary to secure a competent man. Another cause of failure is the subletting of sewage farms to farmers, whose chief object is naturally to make a profit, the efficient treatment of the sewage being considered of secondary importance.

6626. You do not think that on a sewage farm, an ordinary farmer would understand it?—No. You must have a man who is specially trained. If he is to look after a sewage farm he must have been specially trained for that particular kind of work. It is no use taking a man who has been used to look after filter beds to look after a sewage farm, as in this case he requires a knowledge of farming in addition to experience in the treatment of sewage. Similarly it is no use taking a man who has been used to a sewage

farm to look after filter beds; he must have a training in that particular line he is to attend to.

6627. From your experience with trade refuse would you say that a mixture of domestic sewage and trade refuse was harder to deal with than domestic sewage alone?—Yes, it is, undoubtedly; you get a greater irregularity in the flow, not only in quantity but also in quality. The extra volume must be allowed for and the outfall works and sewers must be increased in capacity in proportion to the increased volume due to it; that is to say, supposing the trade waste is equal in volume to the domestic sewage, the works must be designed on a scale estimated to deal with twice the volume of domestic sewage, and the dry weather flow must be estimated at a time when the trade waste is flowing. When sewage containing any considerable amount of trade waste is treated on land I should consider it advisable that there should be preliminary treatment in precipitation tanks. Certain sorts of trade waste do undoubtedly complicate the treatment of the sewage with which they are mixed, but this difficulty may be overcome by preliminary treatment before admission into the sewers, which need not, however, be carried to the extent of purification, the object aimed at being firstly to intercept any solids in suspension which might cause silting up of the sewer, and secondly, to prevent undue difficulties being created in the treatment at the outfall works. The waste from breweries, distilleries, and woollen works increase the difficulties of treatment at the outfall if the volume in proportion to the sewage is considerable, and preliminary treatment by precipitation should be adopted; in the case of woollen works this treatment may be confined to the extraction of the grease from the more highly polluting portions of the waste.

Tannery waste contains a large amount of solid matter which should be intercepted before entering the sewers. The waste from the works of fellmongers and similar trades is of a very foul character, and contains a large amount of organic matter. It should be given preliminary treatment before being admitted into the sewers, but even if this is done, not only the increased volume but also the larger proportion of organic matter, as compared with ordinary sewage, will have to be taken into consideration in making the necessary allowance at the outfall works. The waste from dye works, chemical works, and ironworks should pass through subsidence tanks without chemical treatment before admission into the sewers. These tanks should be sufficient to intercept the solids and to equalise the flow. It is especially necessary to equalise the flow in the case of ironworks, where tanks of acid liquor are let off periodically. If this liquor is discharged uniformly into the sewers it assists precipitation, whereas if it is discharged in large quantities at intervals it complicates the treatment at the outfall.

6628. Have you any experience of sewage going into tidal rivers or the sea—personal experience?—I have very slight experience.

6629. Very slight?—I have some; I know that they have complaints in Lancashire outside the Mersey of mud on the foreshore near Formby.

6630. You have never had to consider the effect of sewage on oysters or mussels or shell fish?—No, not at all; no.

6631. (*Mr. Killick.*) With regard to the suitability of land to purify sewage, I suppose your opinions are summarised in the table which you have handed in?—Yes, that is so.

6632. Could you briefly tell us how you formed these opinions?—On the Mersey and Irwell watershed the Stretford Farm is one of the most satisfactory ones, and the effluents obtained from it are invariably good; the subsoil is alluvial; the farm is drained throughout. In 1895 the population (8,500) draining to it was at the ratio of 200 persons per acre, but the land was found to be getting overworked, and an extra area has been bought which has reduced the ratio to 150 per acre. The farm is arable, and deals with the whole of the storm-water except in exceptional storms. A good example of a broad irrigation system is the Croydon Sewage Farm at Beddington, where the storm water and sewage from a population of 100,000 persons is dealt with on an area of 450 acres, giving a ratio of 222 to the acre. The farm, however, is worked to its utmost capacity, and the engineer is now putting down contact beds with the object of reducing the amount of sludge which tends to foul the land; it is very suitable as regards position and fall, has a gravelly subsoil, and is very well laid out. It is evident therefore, that even under the most favourable circumstances a ratio of 222 persons to the acre is too high for a broad irrigation farm; 100 is probably a safe limit to commence with, which might be raised in exceptional cases to 150. Peat land is quite unsuitable for broad irrigation, as without efficient drainage the peat becomes waterlogged; it can only be used, therefore, on the intermittent system. The Altrincham and Wilmslow (southern) farms both contain a considerable amount of peat, and are underdrained. The Altrincham Farm deals with 340 persons, and the Wilmslow Farm 300 to the acre, but in neither case is the storm water dealt with to any extent. Under proper conditions I think that 100 to the acre is the maximum ratio which should be allowed. Clay land can only be used on the broad irrigation system. It must not on any account be drained, as cracks occur in dry weather, which permit the sewage to find its way unpurified into the drains; these cracks extend to a considerable depth, and I know of no means by which they can be avoided.

At Tyldesley (population 14,500) and West Houghton (population 10,500) clay farms were in operation in 1895, the ratio of persons to the acre being in the case of Tyldesley 100 and West Houghton 175. The treatment in both cases was a complete failure, and precipitation tanks and filter beds had to be constructed.

As to the amount of sewage which can be treated on a clay broad irrigation farm I should say that the ratio should not be greater than 50 persons per acre; it is possible that this estimate is a too hopeful one; the whole of the treatment will have to take place on the surface, and longer periods of rest will have to be allowed for the land to dry, as this will be effected more by evaporation than by percolation.

Clay land is wholly unsuitable for intermittent filtration for reasons stated above, but it may be turned into filtration plots by burning the clay, as has been done at Wimbledon. Lightening clay land with cinders has also been attempted, but although this course may improve matters for a time, I cannot think that the improvement will be permanent.

Comparing arable land with pasture land is somewhat difficult, as I know of no cases of a sewage farm being entirely pasture; as a rule only a small portion (if any) is pasture. I should say, however, that pasture land will not deal with the volume that arable land will deal with, owing to the fact that the surface of the pasture land cannot be ploughed and aerated, conditions of great importance to the success of a sewage farm.

6633. At Stretford is the whole of the storm-water treated?—Yes the whole of it; it is very exceptional that any storm-water flows over.

6634. Is the sewage treated before going on to the land?—No, it is passed on to the land direct, and the land is underdrained, and therefore I have included Stretford under the intermittent filtration in the second part of that table.

6635. Peat land you describe as unsuitable for broad irrigation, but suitable for intermittent filtration; have you any instance of peat land?—Yes, Wilmslow. Wilmslow is one instance where it is underdrained. They do fairly well there, but they do not deal with a large volume of storm water. Altrincham is overdone at the present time, and application has been made to the Local Government Board for borrowing powers to increase their area. We have had good results from Altrincham. Peat land must be underdrained, because being so absorbent, unless it is you would never get rid of the water from it: it would be always in a spongy condition.

6636. And underdrained peat land is suitable for farm treatment?—Yes, it is.

6637. In this table have you calculated for the normal flow or from a multiple of the normal flow?—In this table I have estimated that the areas which I give should deal with three times the dry weather flow.

6638. Three times the dry weather flow?—Yes, with the exception of the clay land. It is very difficult to say what volume clay land will deal with, because the sewage must not in any case flow through it. You must not underdrain clay land. If you do, cracks occur in the summer and the sewage finds its way through the cracks direct into the underdrains. I think in that table some allowance would have to be made for storm water on clay land, otherwise with the light gravel and heavy loam the areas which I have given should be capable of dealing with the whole of the flow, with certainly three times the dry weather flow, and up to as much as six times occasionally in the case of a very heavy storm.

6639. In all cases do you think that land is necessary even after the sewage has been treated by chemical fil-

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tration or bacteria beds?—No, I do not think it is necessary. We get very good results from bacteria beds and from filters. We get results which are quite good enough to go into a stream which is not used for drinking purposes.

6640. Could you give us any instances of effluents from bacteria beds in your watershed?—We have good results from Oldham. They have the largest area of bacteria beds.

6641. Could you give us any figures in regard to Oldham as to the area of the bacteria beds or the volume that they are treating?—In the early part of this year they had an area of 18,920 square yards, and they were treating at that time—I am not perfectly certain of this figure, but the dry weather flow is 3,250,000 gallons, and they were treating about half at that time on their bacteria beds.

6642. About 1,500,000 gallons?—About 1,500,000 gallons.

6643. And what is the whole process in this case of the bacteria beds at Oldham?—In the first instance the sewage is passed through settling tanks; at the present time no precipitant is used at all; it is merely passed through the settling tanks, and the effluent from those is passed direct on to these bacteria beds.

6644. And are those effluents satisfactory that come from the bacteria beds?—Yes, they are perfectly satisfactory; they always come within the limits; they are generally about ·7 or ·8.

6645. How long have any of these bacteria beds at Oldham been working?—About two years.

6646. Do you know how far those beds have decreased in capacity?—No, I cannot tell you that.

6647. Is it single or double?—It is single filtration.

6648. Single contact?—Yes.

6649. Have you another instance of bacteria beds in the watershed?—They have bacteria beds at Romilly, but it is a very small place. I do not think it is a good instance to give you. Swinton is another place where bacteria beds have been used—that is to say, when I say bacteria beds I mean the sewage has been held up in a bed instead of being streamed through.

6650. At Swinton have the beds been in operation for some time?—Yes, they have; but they are not very satisfactory at present. They have been overdone, they have been overdosed.

6651. Have you any opinion as to loss of capacity?—No; I have not as to loss of capacity. I have a number of places where filters are used where the sewage is streamed through them, such as Astley Bridge; they have polarite and cinders there, and Mossley, polarite and sand, and a large number of other places. Heaton Norris is a good place; there they get good results from sand filters after precipitation.

6652. All these places turn out satisfactory effluents?—Yes, they do.

6653. And some of them have been working for a fair length of time?—Yes, a fair length of time—some years. I may say the tendency is always the same with land as with filter beds, it is always to overdo the filters and the land. As the population increases provision is not always made for that increase, and that is accountable for a great many failures.

6654. Should storm overflows be fixed or movable?—They should be fixed, as a rule. If sluices are used they should only be used simply to protect the works on an emergency, if a big flood comes down that it is impossible to deal with.

6655. That is at the outfall works?—At the outfall works, and it should certainly be under the sole control of the manager; it should not be possible for any workman to open the sluices and let all the sewage into the river; the manager should have personal control over them, and I think if the sluice is used, on every occasion he ought to notify the river authority that it has been necessary to do so.

6656. At what point would you fix these sluices, the overflows?—The fixed overflows?

6657. Yes; what point, what time, what dilutions?—It is very difficult to answer that question, because it varies with different places so much, but I should think that six times the dry weather flow is a very fair amount to treat. I think that if they do treat that volume the remainder should be allowed to flow over the overflow.

6658. And the overflows in the sewers, what should you fix those at?—I should fix those at the same dilutions; you are supposing you have overflows on the line of the sewers.

6659. On the line of the main sewers, yes?—They ought all to be the same.

6660. Have you any observations of overflows over any line of sewers or at the outfall works as to the time they come into operation; the length of time they are in operation, and the volume of the overflow?—No, I have not.

6661. Would it be possible by arrangement with the authorities to get some evidence on these subjects?—It is very difficult. At Manchester, for instance, there are a large number of storm overflows on the line of sewer, and the total discharge would be very difficult to calculate.

6662. It would be an advantage if one or two typical cases were to be chosen and watched?—At the same time taking observations of the result of the dilution, you mean?

6663. Yes, and of the time taken?—And of the time taken, yes, it would no doubt.

6664. You see you are asked a question here: "Assuming the overflows are fixed at such a point that they will not come into action until the sewage, during that part of the day when it is flowing at the maximum rate, is diluted with five times its volume of storm water, what may be expected to be the maximum total volume of sewage delivered at the outfall during any one day of 24 hours in a town (a) having a complete system of surface water sewers; (b) having no separate system?—Yes.

6665. Those questions must be answered from some estimates in your own mind?—Well, the flows at Manchester have been taken.

6666. At the outfall?—At the outfall works; I think you have that information before you.

If a complete system of surface water sewers has been put down, the volume of water delivered at the outfall works will not be materially affected by storm water, and the maximum total volume will consist of the water consumed for domestic and manufacturing purposes, if the latter is turned into the sewers, in addition possibly, to a small quantity of subsoil water. These are all variable quantities, the water supply may be anything between 10 and 60 gallons per head, and must be known definitely before an estimate of the total volume of sewage can be made.

If there is no separate system for surface water the volume delivered at the outfall in one day of 24 hours will depend not only upon the total rainfall for the day, but on the distribution of the fall throughout the day. In the case of a heavy fall of rain of one hour's duration, possibly one half of the increased flow due to the rain would pass away by the storm overflow, whereas if the same fall of rain were distributed over three or four hours the whole of the volume might flow to the outfall. An estimate of the maximum total volume to be expected can therefore only be approximate, but it may possibly be taken at from 3 to 4 times the dry weather flow. At the Stretford outfall the maximum volume pumped in 24 hours is slightly in excess of 3 times the dry weather flow; the sewage is pumped from a large receiving tank which to some extent regulates the flow; it is on very rare occasions that the storm overflow comes into operation.

This total maximum volume will be delivered at rare intervals only, probably less than six times a year, but provision will have to be made for it.

6667. Do you not think it possible if the Chairman was to write to the Mersey and Irwell Joint Committee, asking their help to obtain this information, that in conjunction with the sanitary authorities we might arrange to obtain some reliable data?—Well, we could do our best to get it. You want some place where, if possible, all the sewage comes down to one overflow. In most towns you have overflows all along the line of the sewers, as you have at Manchester. It is a most difficult thing to estimate all those, and what the discharge would really come to.

6668. You could not take it for the whole city, but if you took typical instances of either flat country or hilly country and kept a record of the rainfall, it would be useful information?—Yes; well, if I am asked to give that information I will do my best to obtain it. But as regards the very high floods, those which are up to six times the dry weather flow, there is no doubt they do occur very seldom. At Stretford I know that the storm overflow very seldom overflows.

6669. Do you form any estimate as to the amount in 24 hours the sewage works would be called upon to treat under the conditions of the heaviest storm recorded?—I should think roughly three or four times the dry weather flow that is treated at Stretford.

6670. (*Colonel Harding.*) You have not said anything to us about sand, sandy land, and its suitability for filtration. Have you any experience of sandy land, and especially of red sand?—No, I have none, not of actual sandy land, only light loam.

6671. In your area you have not any sandy lands?—No, we have none at all.

6672. I think you mention that in regard to subsoil water, sites should not have subsoil water at a less depth than 5 feet from the surface?—Yes; that is so.

6673. Your idea being that 5 feet of percolation is necessary for purification for most soils?—I think it is a great advantage to leave 5 feet if you can get it, but in any case your subsoil water ought to clear the drains below entirely.

6674. But in certain cases, especially if there is preliminary settlement less than 5ft. percolation should give adequate results with suitable lands?—Yes, they do, but I should think from 4 to 5 feet is more satisfactory.

6675. It is obviously desirable if you can get it?—Yes, it is.

6676. But I suppose I may take it that where you have preliminary treatment, say, by septic tanks and bacteria beds, to some extent not purifying the sewage, but partly purifying the sewage, a considerable less depth than 5 feet would be sufficient for the final purification?—We have cases, no doubt, where it is as low as 3 feet 6 inches, and you get good results. It can be done, but it requires more careful watching.

6677. There are cases where it is suggested that passing bacteria beds over lands would be an advantage where a sufficient degree of purity is not reached by the bacteria beds, and where the effluent has to be passed finally over land. In those cases I should think much less than 3 feet would be sufficient?—Of course, the land would have much less to do then.

6678. In calculating the area of land required, I suppose the thing to guide you is the amount of water which can be percolated through the land apart from the impurities, especially dissolved impurities, which such water may contain?—Quite so; that is one factor.

6679. It is an important factor, is it not?—Yes, a very important factor.

6680. So when we speak of storm waters, though they may be very dilute, and contain a comparatively small quantity of impurities, there is a limit even with storm waters?—Certainly there is.

6681. That being the amount which can be percolated through a given quantity of land?—Yes, that is so; unless you use it with broad irrigation, and flow over the surface.

6682. And I notice that you say that where storm waters are to be dealt with on land, the area of the land must be calculated upon the maximum volume of the storm water?—Yes.

6683. You do not think in the case of a farm which is laid out upon the volume of the dry weather flow, that storm waters can be dealt with at all?—No; not if it is only laid out to deal with the dry weather flow.

6684. In regard to the necessity of settling solids whose sewage is going upon land, you say that except in situations where villages and dwellings are remote from the sewage farm, it is desirable to settle the solids?—I think it is better to do so

6685. I gather from that that your opinion is that it is the solids and the decomposition of the solids rather than the dissolved impurities that cause nuisance on a farm?—Exactly; if the farm is at all overworked, the solid matter is liable to remain on the surface of the land, and in hot weather, no doubt, that may cause a nuisance.

6686. You have spoken about the difficulty which arises from the mixture of trade effluents with sewage on account of the variation in the composition of the sewage coming into the works?—Yes.

6687. Therefore, I take it, that where you have mixed sewage, you consider it very desirable to have an equalising tank?—In the works.

6688. As a first process; to have a receiving tank which would equalise the sewage?—You mean before it goes into the sewers, or after?

6689. No, I mean before it is treated on the land?—Well, what I should very much prefer is to have a tank at the manufactory, so that, for instance, in the case of a dye works, when they run off their dye tanks, the volume of dye water should not come down with a rush to the sewage works.

6690. You suggest a tank at each work so that there should be an equalised flow spread over the 24 hours, instead of a rush at any part of the day?—Yes.

6691. An arrangement taken already in many places?—Yes, that is so.

6692. If at the sewage works there was a receiving tank to be used either as a settling tank or a septic tank, if it were of adequate area you would not mind these occasional rushes, because there would be an equalisation of the sewage by such tank?—I do not think you would get it really equalised in that way.

6693. Not if it contained 24 hours' supply?—That means a very large tank.

6694. Yes?—No, I would rather have the ordinary tanks increased in number, because if you have a large receiving tank you have to deal with the sludge in any case, which is a great difficulty from a large receiving tank.

6695. Then I gather from your answer that you think it very desirable that where trade effluents are turned into sewers there should be a settlement of solids before the effluent is passed to the sewer?—Yes, I think that there should be a settlement of solids sufficient to prevent those solids silting up the sewer. That is one object in having settling tanks at the works, and the other is to equalise the flow. I think that unless the trade waste unduly complicates the treatment of the sewage at the outfall that should be sufficient preliminary treatment. At the outfall works it is exceedingly hard to really mix the various effluents as they come, even in one tank. Sometimes when a lot of dye water has been passed into the works you can see it passing forward in a sort of column, as it were, through the tank. It does not seem to mix with the sewage. I do not think it would assist, therefore, to have a large receiving tank.

6696. You have told us that in your opinion authorities ought to be called upon to deal with these volumes of sewage before the storm overflows come into operation?—Yes.

6697. And you have quite properly pointed out that that is a very large volume for the local authorities to deal with?—Yes.

6698. Do you know any local authority of any importance in your area which actually does deal with six volumes of its dry weather flow?—Well, Stretford, which has the sewage from a population of 8,500 flowing to the outfall, deals with the bulk of that volume; I could not tell you whether it is that exact amount, because we have not got the gaugings, but the storm overflow very seldom comes into operation, and there would be rainfall enough to provide that volume.

6699. Speaking generally, the authorities are not dealing with that?—No, they are not.

6700. Now, as to Manchester, do you happen to know the size of the outfall sewer as it reaches the works at Manchester?—No, I cannot tell you that from memory.

6701. You do not know how many volumes it is capable of bringing?—No, I do not, but it is capable of bringing—they have had floods—I am speaking from memory—up to 150,000,000 gallons a day, I mean the rate of flow of that amount.

6702. But you do not know what it would bring down during short periods. Does it reach anything like six volumes?—Yes, that would be just about six volumes.

6703. You think the sewer is large enough to bring six volumes?—Yes, I think it is.

6704. At a given time?—Yes; I would rather you got these particulars from Mr. Mead; I am only speaking from memory.

6705. And probably a very convenient way of getting what comes to the works, assuming that the main outfall sewer is large enough to bring six volumes, would be a sort of registering float arrangement, would it not?—Yes.

6706. Is that in existence anywhere?—They have something of the kind at Manchester, but it is necessarily a very rough estimate, it is so difficult to gauge these large volumes in a sewer. You get greatly increased velocity when you get that large flow; it is not like having

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a pool and a weir at the end where you have still water to start from; it is much more difficult to estimate it in a sewer.

6707. In your answers you have spoken approvingly of the provision of large settling tanks?—Yes.

6708. And you have suggested that the area might with advantage be such as to take in two days' supply?—That is supposing you have to deal with six times the volume.

6709. And in that case for the normal flow the sewage would stay 48 hours in the tank, and in the case of a flow of six volumes would stay about six hours?—No, I should not leave the normal flow in the tanks for that length of time; I should only use a portion of the tanks.

6710. You do not think it is advisable to leave it 48 hours in the tank?—You must not leave it until it begins to putrefy, unless, of course, it is a septic tank.

6711. I was assuming a tank of that capacity you mean to use it as a septic tank?—In that case there would not be that objection.

6712. Have you formed any opinion as to a septic tank as to the time the sewage should remain in the tank—that is to say, the rate of flow?—I can only tell you from what I see they are doing at the various works. What I try to get is 24 hours' capacity at least for a septic tank.

6713. You have not of your own knowledge any information as to the advantages to be derived from letting it remain longer or shorter?—No, I have not got that information.

6714. You mentioned that there was a large tank at Moss Side?—Yes.

6715. And that it failed because of the difficulty of removing the sludge from it?—Yes.

6716. What was approximately the area of that tank at Moss Side?—I should think it would be—I will see if I have got the actual figures here.

6717. Quite roughly?—Two acres I should think it would be.

6718. And was it used as a mere settling tank, the sewage passing through at a considerable speed, or was it used at such a slow speed as to bring about septic conditions?—No, it was used merely as a settling tank. When the sewage attained a certain volume it flowed over an overflow into this large tank, and the tank filled up to a certain level, at which point it flowed over into the river direct, leaving the solid deposit in the tank, and then the water was drawn off gradually afterwards when the solids had settled.

6719. This difficulty of removing sludge is an engineering difficulty?—Yes.

6720. And probably there were questions of level in that case which made it difficult to remove the sludge?—In the ordinary case of removing the sludge you have to allow a fall, and your tank is concreted in the bottom, and so on, and flows direct to the sludge channel. It is all arranged for removing it easily, which is a very important point. But in regard to these large tanks either you must construct it with a proper concrete floor and a fall leading to a channel, in the same way as you would for ordinary settling tanks, or you would have a difficulty with the sludge; that is to say, if you have a large open tank with merely a puddled bottom—I think it was puddled at the bottom—you cannot remove it except by wheeling the sludge out with a wheelbarrow.

6721. That is what I wanted to get at; is the difficulty in the case of a large settling tank of that kind that there is sludge when the upper water has been removed down to the level of the sludge that the sludge will not flow—will not the sludge flow?—You must construct your tank so that the sludge will flow.

6722. But with a considerable area merely puddled, would not the sludge flow by an outlet at one corner, for instance—No, it would be too large.

6723. It would not flow?—No, it would not flow.

6724. It would have to be pushed?—Yes, you would have to push it in any case; but what I mean is this: you would have practically to make your flood water tank as efficiently as your ordinary sewage tanks, and I would sooner spend the money on making more ordinary tanks than on this flood water tank.

6725. It occurs to one that apart from that difficulty no doubt there are engineering ways of getting over it. A very cheap septic tank might be made if it were simply an area of flat ground banked round so as to form a large septic reservoir?—An open septic tank.

6726. Yes?—For the flood water only?

6727. No, for receiving the sewage and dealing with it specifically?—Are you supposing you never would have to clean out your sludge from the septic tank?

6728. No. I say that is the only difficulty you see of having such a large tank?—Yes.

6729. The difficulty of removing the sludge because it will not flow to one or more outlets?—That is the chief difficulty, I see, yes. The difficulty of dealing with the sludge is always a serious one at sewage works, and you must make it as easy to deal with as possible.

6730. You have not yourself any experience of sludge from septic tanks on this point whether it is easier to deal with more readily dried and less objectionable, or more objectionable than the ordinary sludge from rapid settling tanks?—It is more objectionable, no doubt, as regards smell from it. It was very objectionable at Manchester. They cleaned out an open septic tank they had there, and it was very objectionable indeed. In that case it was not pressed; it was pumped to the sludge ship, and put out to sea.

6731. The question of septic tanks I would suggest to you is one well worthy of your attention; you have a few examples of it in your area?—Yes.

6732. And it would be very interesting indeed to really ascertain the extent to which nuisance arises or is likely to arise from septic tanks, and their digesting of sludge in septic tanks, and the most convenient way of removing sludge from septic tanks?—The question of the reduction has been dealt with, I know, in Manchester.

6733. They have given an opinion. I know Mr. Fowler has suggested that it is about 50 per cent.?—Yes; and as regards the nuisance, that only occurs seriously when the tank is being cleared out. I do not think there is more nuisance from the septic tank than from an ordinary settling tank to any great extent.

6734. That is found to be the case where you are dealing with sewage like that of Manchester and Leeds, which is diluted, and which is mixed with trade effluent?—Yes.

6735. But I am told that open septic tanks, where you are dealing with domestic sewage, especially a strong domestic sewage, gives rise to considerable nuisance. That is a point which we would like you, supervising as you do a large number of sewage works, to carefully take notice of?—Yes, I will certainly do that, but at present we have no open septic tanks dealing with ordinary domestic sewage; they are all closed, and from those there is no nuisance.

6736. Except at the outflow?—Except at the outflow, yes.

6737. (*Chairman.*) Did you say you know of open septic tanks dealing with domestic sewage?—Not with purely domestic sewage.

6738. Then all the tanks you spoke of to me when we were talking of it at the first, deal with trade refuse and domestic sewage combined?—Manchester deals with the two combined, the others, dealing with domestic sewage only, are covered.

6739. It is very likely, I suppose, that trade refuse and sewage combined would produce much less smell than the domestic sewage; that seems to be the case at Leeds, certainly?—It may be so, yes.

4740. (*Colonel Harding.*) Then it would be interesting to see whether the smell which you have noticed in the covered septic tanks dealing with domestic sewage arises from its concentration at the point of outflow; whether if the tank were open and the gases were diffused the nuisance might be greatly reduced. That is a point, I think, that you have watched?—Yes, I should think that in the summer time, certainly, when you have the greatest objection from the smells, I should say that the covered septic tank was less objectionable than the open septic tank.

6741. Why? Is the nuisance due to the decomposing scum, or is the nuisance due to the evolution of gas from the bottom of the tank?—I should say from the evolution of gas.

6743. I do not quite see why the covering in is to prevent that; the gas cannot be stored under the roof, it must escape?—The gas is burned at the tank in Manchester. They light it at the top of the covered tank, that is the covered septic tank.

6744. Then you suggest that by covering a septic tank it would be possible to destroy the gases by combustion?—Yes, and that apparently has been done at Manchester.

6745. It would involve very careful construction of the

tanks, which would really become gasometers?—That is so. It is a brick tank with an arched roof.

6746. Apart from the possibility of consuming the gas, you do not see much use in a roof, do you?—No, I do not think there is.

6747. (*Major-General Carey.*) With regard to the terms, broad irrigation and intermittent downward filtration, is there not some misunderstanding in the expressions in your replies. I notice on the table attached to the sixth question the proportion of population to the acre for intermittent filtration is only very slightly above the same rate for broad irrigation. Is not a farm laid out and underdrained for intermittent filtration perfectly distinct from a large area laid out for broad irrigation in respect to the volume of sewage which can be treated on it. All sewage is applied intermittently?—Yes.

6748. Whether it is broad irrigation or intermittent filtration, or any process, all sewage must be applied intermittently to land?—Yes.

6750. Therefore the fact of its application being intermittent, does not make the distinction between the two processes?—No, quite so.

6751. Nor, I think, does the distinction which you have given either meet the case—that is to say, that a broad irrigation farm may or may not be intermittent; there may not be drains at close intervals, but there may be intercepting drains which take the effluent and discharge it into the stream at some point below the farm?—Yes.

6752. It does not follow as a matter of course that there is no underdrainage on a broad irrigation farm?—No, it does not follow that there is none at all, but there is, at any rate, very little for a broad irrigation farm, and that is the division line that I have drawn between the two.

6753. But when the area is laid out in level plots, say in acre plots with suitable land, and it is underdrained, do you say that you could not treat more than the sewage of 150 persons to the acre?—Yes, that is my opinion,

6754. Have you any examples of intermittent filtration at all within your watershed?—Stretford is a case of intermittent filtration.

6755. What is the area?—The area is 57 acres.

6756. And the population?—A population going to that farm of 8,500; it works out to 150 persons per acre.

6757. Then why should you call Stretford as intermittent filtration?—Well, it is drained throughout; it is not surface treatment.

6758. But the sewage is distributed by contour gravitation. The land is not level; it is laid out in plots?—The land is naturally level, there is no difficulty in that way about it; in some places you have the plots laid out on the hillside, where it has to be artificially levelled; but it is exceedingly level land.

6759. And the land is suitable?—Yes.

6760. Is it laid out in acre plots?—No, they vary.

6761. And you have only put the sewage of 150 persons to the acre on that land?—That is all.

6762. On that prepared land?—Yes.

6763. Do you know Dewsbury?—No, I do not know it.

6764. Perhaps you will remember Mr. Bailey Denton's first introducing the system of intermittent downward filtration?—Yes.

6765. In which he claimed that by preparing the land in this way, levelling it and underdraining it, he could treat and purify the sewage efficiently of a population of nearly ten times as much as he would do by broad irrigation?—I can only judge from my own experience.

6766. And in 1868, I think, the Royal Commission came to the conclusion that it was under the mark—that instead of 1,000 persons to the acre, 3,000 persons to the acre could be treated.

6767. (*Mr. Killick.*) Is it not really the case that there is not such a thing as broad irrigation—it is all intermittent filtration?

6768. (*Major-General Carey.*) No sewage could be put continuously on the whole farm; it is all applied intermittently?—I quite agree, and I think the description is wrong really. I meant to say you cannot draw a hard and fast line between broad irrigation and intermittent filtration. It was given here in the questions, and I did my best to answer it. Intermittent downward filtration is the better term as opposed to the more horizontal flow in broad irrigation.

6769. I must say I was exceedingly surprised to see your proportions in the table, because as far as I see it makes no difference whatever between a broad irrigation farm and land laid out for intermittent downward filtration?—You get 50 per cent. more. *Mr. R. A. Tatton.* 15 Nov. 1900.

6770. Yes, 50 per cent.?—In the case of light soil one great object in the underdrains is to enable land to dry itself quickly to get rid of the sewage. If it is light soil the water will flow through the soil without drains and get away.

6771. In a very porous soil?—Yes, in a very porous soil; and therefore you do not get that immense advantage which you would expect in under drains. If your soil is porous enough to let the water get away without under drains, then the under drains do not help you.

6772. Supposing you have a medium soil and is laid out in plots levelled and underdrained, does it not approach to a great extent to a bacterial filter in which you say that sewage of 1,000 persons to the acre can be treated?—You cannot get rid of the water at anything like the rapidity with which you do with filters. You can empty your filter quickly, and you cannot get the land dry quickly, not nearly so rapidly as you would on a filter bed.

6773. Surely in a fairly porous soil there is not the difference between the sewage due to 150 persons to the acre and 1,000 persons to the acre in a bacterial bed?—But you would not pass raw sewage on to a bacterial bed. I am considering that a filter bed with 1,000 to the acre would not be raw sewage; it would be tank effluent, clarified tank effluent; it would compare to the third column, which gives a population of 500 to the acre after precipitation.

6774. You assume that no sewage can be put on a filter without being treated?—Yes, I do.

6775. Is that what you mean?—Yes.

6776. I think in Dewsbury, which I understood was a typical site of intermittent filtration, that the sewage was really not treated at all except passing through a small tank before going on to the land?—I do not know Dewsbury. Of course, one has to be quite sure that all the sewage is passed through the land. In comparing this table for filter beds you must take the third and the fifth column to compare. For instance, gravelly land, I think, 500 to the acre after precipitation, and 1,000 to the acre after it has passed through filter beds. That seems to me to be the proper one to compare.

6777. 500 to the acre after precipitation or mechanical settlement, is that right?—Yes, that is right.

6778. And 1,000 to the acre after passing through the bacterial beds?—Yes.

6779. Is that proportion, 1,000 to the acre, based on an actual experiment?—No, I do not think it is. The chief factor there is what the land will actually pass through it. I consider that if the precipitation and the filtration process is efficient there ought to be very little actual purification for the land to do.

6780. If filtration is efficient?—Yes.

6781. If the sewage is so entirely purified in the bacteria beds the land will have very little to do?—Yes.

6782. Of course, that means first-class management?—Yes, that is so.

6783. Of the bacterial treatment?—Yes, that is so.

6784. And you would require for that purpose quite as efficient and competent supervision as you would for a sewage farm?—Oh, certainly you would.

6785. Quite as good?—Yes.

6786. Is not a bacterial process rather more complicated to deal with than ordinary land treatment?—I do not think it is more complicated; you would have to have special training for it.

6787. Double contact beds with valves open and closed in order to ensure proper purification is not more complicated than settling tanks and land or land by itself without the tanks?—I do not think it is more complicated. I do not see why the one or the other should not be properly managed at all; but, of course, you must have an efficient manager to do it.

6788. If the bacterial treatment is not properly carried out there is a failure to produce a satisfactory effluent; in fact, if it is only partially purified, as you yourself have suggested, is it not desirable or even essential that you should be required to ensure proper purification?—If it is not properly purified.

6789. Are you to count upon sewage being properly purified by passing through filters?—I am afraid I can-

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not count on sewage being always properly purified by passing through either filter beds or farms.

6790. Of course it has not been carried out long enough to know how far the sewage will be purified or not, or what sort of supervision will be exercised throughout the country in places great and small, but by analogy of treatment in sewage farms I suppose you can say what the supervision is likely to be?—Well, we have several—I may say a large number—of filtration schemes that are carried out very fairly satisfactorily.

6791. In small places?—I see no reason why it should not be done equally well with large places. I think it is a great advantage in large places if you have an exceptionally capable man to manage the sewage works. I think if you could afford to have a chemist it would be a very great advantage. He would be able to ascertain at once if any of his filters were getting overworked, and take steps to recover them before the evil has gone too far; through ignorance filters are sometimes allowed to go from bad to worse, until the whole series is hopelessly choked up.

6792. Suppose you have not got them under first-class supervision, and the filters do go wrong, what is the result?—If they are very bad, of course you have to dig them out; but some of these men are very intelligent as to knowing when a filter is going wrong, and then they rest it.

6793. Now, with respect to the storm sewage up to six times the dry weather flow, I understand from your replies that you contemplate that volume having to be taken to the works. But in answer to a previous question you say: "At the Stretford outfall the maximum volume pumped in 24 hours is slightly in excess of three times the dry weather flow"; and in your next answer you say: "This total maximum volume will be delivered at rare intervals only, probably less than six times a year"?—Yes.

6794. Do you intend to convey the impression that six times the dry weather flow will come down to the works as a rule in different places, or that Stretford may be taken as typical of what will happen in other towns in the watershed?—No, I think it depends entirely on the situation of the town. If it is on a hillside where the water comes down quickly you may have a volume of six times the ordinary flow with quite a small amount of rain. For instance, that is so at Eccles. It comes down with a rush, and very soon makes up six times the dry weather flow.

6795. And you have to provide for that?—And you have to provide for that.

6796. You are aware, I mean, that in all schemes which have been approved by the Local Government Board during the last two years the conditions are that the storm overflow shall not come into operation until the sewage shall have been diluted with five times its volume of storm water?—Yes, I know that.

6797. No scheme is sanctioned without the condition that six times the dry weather flow has to be taken to the works for treatment of some kind?—Yes.

6798. Of course, if it were proved that you never had that six times except in very exceptional circumstances it might modify the conditions very much, but can Stretford be looked upon as a typical town for that modification?—You cannot have a typical case at all, but what I should like really would be to have each case taken on its own merits. That seems to me to be the right thing to do, but you cannot have a rate of dilution which would be equally satisfactory over the whole area of any watershed.

6799. Then as to the purification of these six volumes at Stretford, do I understand that six volumes are treated?—I believe that is about it.

6800. One volume of crude sewage and five volumes of storm water are treated?—Yes, it works out about that.

6801. I suppose the whole of the land is not taken into use at the same time; only one portion of the land is under irrigation?—Certainly.

6802. And the remainder has a rest?—The land will not be flooded all at the same time; it would have periods of rest.

6803. Say one-fifth of the land is under irrigation and you have a storm, which brings down six volumes altogether—five volumes of storm water to one of sewage—to the works, will the sewage and storm water be put on that part of the land which is under irrigation, or will it be at once taken over the whole farm to be treated?—Well, it would not be taken over the whole farm, but the area under irrigation would be increased. They would pass it on to another plot. Suppose the farm is divided up into eight plots, possibly one or two are under irrigation for the dry weather sewage; if a storm came it would then be passed over two or three other plots, according to the size of the storm.

6804. But you say they have no difficulty in treating the whole of the six volumes on a portion of their area at Stretford?—They require the whole of their farm to deal with the sewage of Stretford: at any given time they will possibly be treating the whole volume of their sewage on one-fifth or one-sixth of the farm, but the other portions will take their turn; they are all required.

6805. Each part of the farm will come under treatment in succession?—Yes.

6806. But when there is a storm, is the storm water taken to that area of irrigation or is the whole farm irrigated with the sewage and storm water; is the whole farm irrigated with that six volumes?—No, probably not. I should think it would never be, never the whole farm at one time.

6807. And you do not think the land is overtaxed by six times the volume being constantly taken to it?—On to one-fifth of the area?

6808. Yes; we will say that there is 100 acres, for the sake of argument; 20 acres are under irrigation for the time being, and a storm takes places, the whole of that 20 acres has then to be treated with sewage and the storm water up to six volumes?—No, I should extend that 20 acres.

6809. That is what I want to know?—I should put it on to another area; I should extend that area.

6810. You do not know what actually happens at Stretford?—That is exactly what does happen at Stretford. If they had 20 acres being irrigated, then if a storm came on they would not keep that storm water merely on that 20 acres, they would extend it.

6811. On to another 20 acres?—On to another 20 acres or perhaps another 20 beyond that.

6812-3. If it were clear of crops?—Yes, quite so. We will say you are using No. 1 plot to-day; to-morrow you leave that plot to dry, and you use No. 2; the next day you will use No 3, and so on. If a storm comes on you would turn the water on to No. 2 or No. 3. which is the land you were going to use to-morrow, we will say, and perhaps you would have to use one of the other plots.

6814. Still, it would be a great concentration on a comparatively small area?—To put all the storm water on?

6815. The land would be very heavily taxed?—It would be a mistake to put all the storm water on one plot.

6816. You do not consider it would be better to have a separate area for dealing with storm water so as to leave the irrigation area for treatment of sewage and perhaps two volumes of storm water?—No, I must say I do not.

6817. Would you consider it would be any advantage setting apart an area for exceptional storm water instead of flooding your 20 acres or 40 acres used for ordinary volume, during a storm?—No; I would rather increase the size of the farm and be able to use the whole of the land for any work that is required; I would rather not keep any particular plot for storm water; I do not see any advantage in that.

6818. When the land, we will say, is overtaxed with the sewage and the storm water, the portion of land that you are going to use does as much as ever it can do; it does not improve that, you think, for irrigation when the storm is over, the fact of this immense volume having been put over it, perhaps in two or three days. That land has to recover itself?—Yes, it has.

6819. It is not fit for some little time for ordinary irrigation; it cannot begin its work of purification the moment the storm has gone down?—It would as soon as it had dried itself and had a proper period of rest. The storm water would not do more harm to the land, apart from the volume, than sewage, in fact, less, because there would not be the organic matter to deal with in storm water as in ordinary sewage.

6820. No, that is perfectly true, but there would be an immense volume on a comparatively small area, because I do not suppose for a moment that you would put the whole of that storm water on the whole of the farm. You say yourself 20 acres are under irrigation for crude sewage, and you would take another 20 acres, perhaps, and put that six volumes on those 40 acres, but still that would be taxing it very severely?—But still, if you had a small area set apart for your storm water, you would tax that small area very much.

6821. I do not say small area, I suggest you should set apart a sufficient area, or have special artificial filters, so as to have your irrigation area always ready and fit for the treatment of crude sewage, with, perhaps, a small proportion of the storm water?—

6822. You say in answer to question 17, about separate systems, "In separate systems it is usual to connect the back yards of houses to the sewers, the water from the roofs and streets going into the storm drains, unless the streets are kept unusually clean the water from them, especially at the beginning of a storm, will be foul, and will cause pollution of the streams. This difficulty can be got over by means of "leaping weirs," which are commonly used on waterworks for diverting turbid flood water from the pure supply, and which would allow the first portion only of a storm to fall into the sewers. The extra cost entailed is a serious consideration, and this is especially so in the case of a town already provided with a single system of sewers." Then in that case it would not be a separate system at all would it, because you are letting your storm water into the sewers?—Yes, you are; it would not be a complete separate system.

6823. I say it would not be?—No, it would not; the street water would go into the sewers, the polluting street water.

6824. I do not quite understand your answer to question 19, "The ratio between storm water and sewage beyond which point a storm overflow is to be allowed to act, must be calculated on the maximum rate of dry weather flow." What has the storm got to do with the maximum rate of sewage coming down; a storm may occur at any time, may it not?—Yes. What I mean is this, that if you start with the idea that you are to treat six times the dry weather flow in case of storm you must base that six times on your maximum dry weather flow.

6825. Not on the average?—Not on the average, no.

6826. (*Mr. Power.*) On the forenoon flow in dry weather, you mean?—Quite so, yes.

6827. (*Major-General Carey.*) In answer to question 20, you say: 'If a complete system of surface water sewers is provided, overflows on the sewage sewers are only required to act as safety valves in order to prevent the sewer being put under pressure in case of accident or stoppage; they should never come into operation otherwise." But is such a complete separation possible? Is there not much subsoil water frequently getting into the sewers?—There will be some no doubt.

6828. A sewer is never so water-tight that nothing gets in except the actual sewage brought down?—Yes, but that will not be increased by the storm to any extent.

6829. No, it might not be increased by the storm at first, but it might afterwards by subsoil water, when part of that storm would be absorbed by the ground?—Yes, no doubt; but your storm overflow should hardly be set in operation by the subsoil water.

6830. No, that is quite right. Of course if a storm overflow is not provided on a line of sewers, if you have no safety-valve in fact, the sewers must be designed to take the dry weather flow and practically any amount of storm water which may come down practically. Although there is a separate system, you can never provide for rigid exclusion of all storm water?—I should have storm overflows as safety-valves, but if you have a separate system I do not think you would ever get a dilution, which would warrant the storm overflows coming into operation.

6831. You say: "An estimate of the maximum total volume to be expected can therefore only be approximate, but it may possibly be taken at from three to four times the dry weather flow." And that is based on your Stretford observations; you have no other observations, have you, that bear out that statement?—No, I cannot give you anything very definite about that.

6832. Then the answer to Question 22: "No storm overflows should be permitted where the effluent passes into streams used for drinking purposes." That is whether it is a combined or separate system. But would not the result of that be that sewers would have to be designed at enormous cost to take sewage and storm water—an unlimited quantity of storm water; is it really practicable on account of the cost?—It is done in some places; at Croydon I believe that is so. I have had it from the engineer when he took me over the works; he said the whole of the storm water came to the sewage works.

6833. Without any overflow?—Without any overflow. Of course I have no personal knowledge. I only had it from him, but I must say I do not like a river being used for drinking water at all into which sewage works discharge or any sewage discharges.

6834. (*Mr. Power.*) I should like to be quite clear about the difference between rate of flow and volume which has actually flowed. You say as regards Eccles, that owing to the rapidity with which storm water reaches the works a dilution of six to one at which the storm overflow is fixed is soon reached. Does that mean that six times the dry weather flow has been delivered at the works, or merely that the flow in the sewer where the weir is very quickly attains a rate of six times the dry weather flow, and that therefore the weir overflows?—That is so; it is the rate of flow we are dealing with in the six times.

6835. Then as regards Stretford, where you have the overflow weir fixed in the same way, to operate when six times the volume of the forenoon dry weather flow is coming down; nevertheless you never had there more than about three times the dry weather flow, actually delivered within 24 hours at the works—is that so?—That is so, because the actual rate of flow at the six times the dry weather volume may only extend over a short period of time.

6836. That is when it begins to pass over the weir?—Yes.

6837. It does not mean six times the volume of the dry weather flow has already been received at the works. The weir must go on overflowing for some considerable time before the total volume amounting to six times the dry weather flow has come down, must it not—it must overflow practically for the 24 hours?—It is being received at the works as soon as the storm overflow, fixed at six times the ordinary dry weather flow, comes into operation. At that moment six times the rate of the dry weather flow is being received at the works, but possibly that rate will only last for an hour or two.

6838. Exactly?—And therefore your volume, your total volume for the day, will only be perhaps three times the dry weather flow.

6839. Quite so; it must come down the whole 24 hours at six times the rate of the dry weather flow to get six times the volume delivered at the works in 24 hours?—Yes. We must keep the volume and the rate of flow separate; they are quite different points.

6840. (*Chairman.*) Was there something you wanted to say?—Yes, my Lord. There is one point in Question 23: "In what system, if any, do you consider it an advantage to provide a large receiving tank at the outfall for the purpose of equalising the treatment. Assuming you consider that such a tank should be provided in certain cases, how should the size of this tank be calculated?—In pumping systems it is an advantage to provide a large receiving tank to equalise the flow and enable pumps to lift a larger total volume in times of storms." I do not mean by that that the receiving tank is to act as a storage tank. I only mean that it should be of sufficient size to enable the full capacity of the pumps to be got to work before the sewage overflows. For instance, supposing you have to deal with six times the ordinary volume, perhaps you would have two pumps, each capable of dealing with three times the ordinary flow, one pump would be used during the ordinary weather. If a storm was coming on the second pump would be brought to work, and your receiving tank must be large enough to hold a certain amount of the extra sewage beyond the three times the volume until that second pump has got to work. I do not like it being used as a storage tank, because then the difficulties of dealing with the sludge at once come in; you have to clean out a large tank, as sedimentation takes place.

Mr. D. BALFOUR, M.INST.C.E., F.R.S., M.S.I., F.R.M.S., called; and Examined.

Mr. D. Balfour, M.INST.C.E., &c.

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6841. (*Chairman.*) I think you are, Mr. Balfour, a member of the Institution of Civil Engineers?—I am, my lord.

6842. Would you mind telling us whether in your opinion land of all kinds, when used alone and without artificial addition of chalk or cinders or any other material, will properly purify domestic sewage?—I think, my lord, land of all kinds will not naturally properly purify domestic sewage, only land more or less porous in quality and then proportionately in quantity.

6843. May I ask you next whether you consider it is desirable that before the sewage is put on to the land it should go through any preliminary treatment?—I have always been of that opinion, my lord. Crude sewage, absolutely crude sewage, should not be put on land; it should receive treatment either mechanical, chemical, or bacterial prior to application.

6844. So as to get rid of the solids?—To get rid of the solids; that is so.

6845. Is there any particular preliminary treatment that you recommend?—In answer to that, my lord, I refer to two schemes that, should your lordship and gentlemen be wishing to examine anything further, particularly in the Midlands and North of England, I should be honoured as well as pleased if they could be visited. The first one is land, some 25 acres to a population of 20,000. There the preliminary treatment consists entirely of mechanical subsidence—the interception of the solids. In the other case, again near Sheffield, which General Carey did not see executed, but had passed the plans in his capacity then of inspecting engineer, there we use (as he may perhaps recollect) alumina ferric, simply alumina ferric (as a sewage and intercepting the residual, and then passing it on to land of lesser quantity than where we have rule Spence's of Manchester) for acting on the crude in the other case mechanical subsidence. Of both cases I give the recent analyses, which seem to me altogether satisfactory, and I have found no complaints whatever. In the one case the West Riding Inspectors regularly examine and sample the effluent. There has never been one complaint. And in the other case the County Council of Durham act similarly, and there has been no complaint whatever either.

6846. In the case where it is simple subsidence, is there a sort of settling tank or what?—In this way, my lord—the tank is oblong (as a rule oblong), as in this case, and the fall being toward the inlet; and we have a little stepping at the outlet for giving aeration. There are four compartments, decreasing in size as you advance in the tank. The first, containing more solid and flocculent matter combined, is the larger, and where we empty by means of a chain pump, and take the sludge out perhaps once in three weeks; it should never be longer, because it fouls the sewage further than what it naturally possesses when fresh. The other three compartments are less in size and intercepting proportionately lesser solid material, and all draining from the outlet to the inlet, where it altogether is pumped. That is the subsidence tank that we have arrived at in recent years as being the simplest and most effective.

6847. And is there a subsidence tank in the other case that you have mentioned?—Yes, there is, only adding to it the alumina ferric. The deposit is greater than the natural or mechanical subsidence effects, and allowing lesser land then to suffice to meet the cost of the use of the chemical. But the land, I think I might put it as we did at the Inquiry—we aim at having in some cases a maximum of chemical and the minimum of land; in the other cases suitable land wholly, where it is available.

6848. Then may I ask you next whether you have any experience of cases where land has been artificially prepared by the addition of chalk or cinders or any other material, and digging up the top of the land and mixing it with this?—I think it advisable, and in point of cost far better to get the natural land, and I think so even though you should pump in order to obtain it. Certainly where you are precluded otherwise, it may be made effective and is made effective; I have not happened to have been obliged myself ever to have to resort to it on any large scale.

6849. Then might I ask you whether you have large experience as to the effect of frost or snow on purification?—Yes, my works being located more usually in the North and Midlands; though I have works all over, and not very far from London. I did one scheme in 1878, for instance, a scheme of intermittent filtration at Skegness, Lincolnshire, applied to land being a very flat district there—the Fens district—Lord Scarborough, the landowner, laying out the place for development. the sewage was taken inland and dealt with on land, then passed on to the sea afterwards. Well, there the frost is not so heavy as in the north, where I have done more work, but as regards winter cold there we have not had anything to complain of. For instance, the County Council of Durham, the County Council of Northumberland, and the West Riding of Yorkshire have not made any demur to effluents during frosts. In Dantzic and other Russian places, also Canada, they seem to get along fairly well in winter.

6850. The warmth of the sewage, I suppose, enables it to purify?—That is the extra warmth of the sewage, and it is a point bacterially whether anything could be done to warm sewage, as we have still greater heat in the effluent whether it could be imparted to the sewage in order to obviate artificial heating. That is being looked into, I know, by engineers at present; as also chemists.

6851. Well, now, about cropping the land, do you consider that the cropping increases the power of the land for purification?—I do, my lord, and I always advocate and carry this out. Where works are in my hands, we try to keep them for a year after completion, and then I assume the responsibility during that time to show that they can be made to do what we promised originally and advised would take place. In all cases I advise cropping either under broad irrigation or intermittent filtration, and distinguishing between the two. I was somewhat early led into the intermittent filtration system by seeing the late Sir Edward Frankland's model tank at his laboratory at Kensington. There I saw the London sewage coming in black at the one end and at the other leaving transparent. After in this strong plate glass tank passing through about six feet of gravel, it came out a good effluent according to analysis. Then I went to see this system in full operation as a first practical example in the kingdom, at Merthyr Tydvil, carried out by the late Mr. Bailey Denton, M.Inst.C.E. The same at Kendal, which he also carried out on the intermittent system, and in both cases cropped, and I advisedly put it to do so, as it assists the purification by the land.

6852. And what crops do you consider best?—All should be of a thoroughly succulent nature. I was at a place the other day, and saw potatoes on the list of crops. "Well," I said, "what are the potatoes grown here for?" "Oh, they make it more profitable?" the farmer or working manager told me. "But," I said, it is purification we want. How long is it since you applied your sewage to these potatoes, which are not a succulent crop." "Eight to ten weeks ago." "Robbing your sewage areas here to that extent; how much of it?" "Oh, about an acre." "Oh, it is quite wrong; I cannot be responsible for works of this nature if they do not introduce the crops that I advise." To take succulent crops, osiers, of course, as we all know, are succulent, mangold wurzel, cabbages, and ryegrass; of course, the osiers are very much so, and can be well sold when we grow those that are locally in demand in the market. We try to find out what is really in demand and get a fair price.

6853. You think willows are good, do you?—Yes, we find them so absorbent.

6854. Now, when the willows grow, do you not find they exclude the air a great deal?—Well, we try to keep them as far separate in planting so that we may ridge them up; a ridge and furrow system chiefly is the best for intermittent filtration. Being a condensed system I have more particularly dealt with intermittent filtration, as authorities naturally wish to have as little land as possible. We have not found willows objectionable; we do not grow them as a whole crop.

6855. Do you find that the length of time that land is used affects it?—No, I have not found anything particularly of that nature any more than in ordinary agricultural farming where regularly manured. We have not found any decreasing effect providing in intermittent filtration that the intermittency is duly carried on so as to regularly sewage it.

6856. You would say that if the land is properly treated and proper care is taken, it would go on practically indefinitely?—That is my opinion and experience, on the whole.

6857. Without losing its purifying power?—Quite so.

6858. (*Major-General Carey.*) About the proportion of population to the acre?—Yes, I have given it in an appendix.

6859. In the first stage of these notes of these replies to the questions you say from 1,000 to 1,500 persons for intermittent filtration?—Yes.

6860. When chemically precipitated and then artificially filtered, one acre for 1,500 to 2,000 persons?—That is so, sir.

6861. And with broad irrigation, 600 to 1,000 persons. Then further on you say, on a bacterial system of treatment one acre of land should be provided for from 1,000 to 2,000 persons?—Yes.

6862. Now, are these figures given as the result of actual practical experience in the working of sewage farms or bacterial filters, or are they purely arbitrary?—Practically they are based on actual experience, but I must say that as to the maximum, 2,000, it is seldom, if ever, we get that, only in cases what I would call with weak sewage and specially good land. I generally keep the scale a little within, as land may be good in one portion of a sewage disposal ground, but not so good in another, so that to carry it out I have averaged 1,750, being from 2,000 to 1,500, but these are really, as you have referred to, so far ideal: to get practically uniform quality on the whole ground is so difficult.

6863. Have you ever seen sewage really satisfactorily purified at the higher rates? That is to say, have you ever seen 60,000 gallons of sewage purified on an acre of land?—Yes, on portions of the land we would deal with it. If there are 25 acres as I speak of in this example in the north, portions of that will really be sewaged up to 2,000 population per acre; others, again, where we have a little clay, or not at all events so porous, would be less, but the average would be perhaps 1,750, being some of it 1,500 population per acre at that rate, and others 2,000 on the same works.

6864. Does that include when storm water is put in? The volume, of course, is increased; the volume that has to be dealt with, that has to be purified, is causing that land to be very seriously taxed if you are treating 60,000 gallons on one acre, and you have, in addition to that, to treat, say, two volumes of storm water?—One volume of sewage, one volume of storm water, may I take it?

6865. Or you may have more than that. If you have no separate system you may have to treat the whole six volumes, may you not, of sewage and storm water in that proportion of one acre to 2,000 persons. In your opinion is that proportion excessive or not? Is it a fair proportion, a workable proportion, or is it an excessive proportion which cannot practically be carried out?—I think only with separate system practically workable, and have carried such out and not found anything in the way of complaint and unsatisfactory.

6866. Well, will you state where?—These places in the north near Newcastle, at Houghton le Spring, and near Sheffield, as given in the analysis, portions are so treated: difficult to get land 25 acres of uniform quality, otherwise you might apply at the rate of 2,000 all over; but finding, in point of fact, one portion of the land not so good as others in being porous, then we are obliged discretionally to apply sewage by giving the working foreman to understand which we consider the one and which the other. But the average, certainly, that we would give is 1,750, being some of it 1,500, some of it 2,000.

6867. That is, 1,750 would be 52,500 gallons per acre of crude sewage altogether?—Not crude, but subsided sewage.

6868. At Houghton le Spring?—At Houghton le Spring and near Sheffield, and the analyses given there are in the appendix.

6869. You say the size of the simple subsidence tank should be per square yard in the proportion of 250 gallons of sewage in dry weather, and 200 gallons per square yard when combined with chemical precipitation. That depends upon the depth of the tank, does it not?—It does; there is the relative proportion there, but about half a day's sewage where mechanical subsidence to be held in the tank.

6869*. Does that work out? What depth are you supposing the tank to be?—The tanks are usually about at the one end 4ft. 6in., to 2ft. 6in. at the other, having a fall upon them to the inlet.

6870. Then you say that storm water after six times the dry weather flow can be treated on the same land, we will say, in the maximum proportion that you have been giving 1,750 persons to the acre or 2,000?—Yes.

6871. In addition, you want six times that to the volume. That is to say, instead of 52,500 gallons per acre you may have 300,000 gallons per acre to treat?—Yes, in this way, provided that the rainfall is not coming exceptionally on the works, and that we have power to open or have a movable valve, so that when the ground is saturated, as one might say, with the ordinary rainfall falling upon it, there would not in addition on that occasion be six flows to make it as it were super-saturated, and when practically the liquid in the river and that overflowing are identical in quality.

6871*. No, I did not understand you meant to say that. At some point in this treatment you get rid of a portion of the six volumes and turn it into the river direct?—Well, what I have got the Local Government Board sometimes to pass—that, notably, at Barnard Castle. There we have, I should rather say, fixed overflows all along the line of sewer, but when we come to the ground, only one that is movable in the discretion of the manager or the foreman, and, of course, under strict instructions not to abuse the use. I know it is a very delicate point to introduce and to put into the hands of working managers on sewage farms; but, on the other hand, as in factory regulations, they should be made if they abuse things to suffer for it, so that what I say is, at Barnard Castle and other places when the ground is saturated, and saturated with ordinary rainfall, and the sewers running with an excess above six times, why turn this on to the ground already saturated in those circumstances?

6872. That is not the point, above six times. I am now speaking of the six volumes. As I understand during part of the time that six volumes can be coming down if the land is saturated you have some means of turning the excess up to six times into the river direct by some sluice or other means left at the discretion of the manager?—Well, of course, all along the line I should make it clearly understood are only fixed overflows, but one movable at outfall, and that does give rise to the criticism.

6873. We have never allowed that, have we?—Yes, and without this movable one would be a misfortune to the land and make its period of recuperation not so short, when it is saturated also with the ordinary rainfall, or where, like an agricultural yard covered over, you were only putting what is in the sewer on to it; but when you have got, in addition the ordinary rainfall to saturate it, I think it is a misfortune and not desirable to turn also on the sewage and to take up to six times.

6874. And why should you not provide against that by having storm filters?—Well, that is coming more in use only of late.

6875. I am merely suggesting it as a remedy—never mind whether it is coming in—as a remedy to that. Of course, what you suggest is that it should be left to the discretion of the farm manager—at a certain point he may raise his sluice and turn the whole of the stuff into the river direct?—Yes.

6876. While the sewage up to six volumes is on his farm he may by means of sluices get rid of it altogether when he thinks it is rather too much for him?—That is the reason, you know.

6877. We should never allow that?—Bye-laws should be compiled so that a man ought to be fined the same as for a factory for misusing the sluice. If a man abuses his trust get him paid off and fined.

6878. I do not think they should trust him?—In circumstances it is too often done, I daresay, without being duly arranged for, but there it is in some cases actually arranged for that whoever inspects on behalf of the County Council or other method of inspection has only to look at this one outfall valve, all along the line being fixed, and his attention by surprise visit or otherwise just simply to be devoted to that one. I should not have them all along the line in that way, and that was just my reason for it.

6879. But would it not be a remedy, a much more satisfactory remedy, instead of giving the farm manager this discretion, to have separate artificial filters or an area of land on which this excess water can be treated, instead of polluting your farm with it and saturating it, to have a special area where sewage or storm water can be treated?—There is an important point in that, because if we find the abuse was not covered by the inspec-

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tion, and things were not satisfactory, then at greater cost we should have to resort to that, and no doubt an important point in it, I quite confess.

6880. Now, as to underdrainage of land, you say all land should be underdrained more or less?—Yes.

6881. Whether broad irrigation or intermittent downward filtration, or any process, in fact, of treatment, the land should be underdrained?—Yes, that is my opinion.

6882. You do not make a distinction between broad irrigation and intermittent downward filtration by saying the land is drained in one case and not in the other?—No, my experience is to drain, to drain it proportionately to condition, but generally to have some drainage, and so always command an effluent that can be inspected, but have a drainage proportionate to the porosity of the land. I think with a volume such as that put upon the land it really wants some artificial relief to some extent more or less.

6883. Would you underdrain clay land?—I have done it; but, as a rule, as I have put it, I never try to find a clay land, and rather pump than adopt a clay land, but I know there are unsatisfactory cases. I have never had such myself, because mine has never been actually clay; it may have been more or less tenacious. I know, for instance, Harrogate is unsatisfactory. I have seen it myself. It cracks. There they went and roughly filled up the trenches, and that made it worse. Perhaps Sir Robert Rawlinson advised in those days that the trench should be filled up with large stones. Instead of filling it in with the clay, it was filled up, I understand, with the large material, large pieces of stone and rough gravel into the trench, then sewage gets down the readier to the drains. I do not know whether it is true or not, but it is an illustration of cases if it had been filled in with the clay instead of a rougher material of stony nature, it would be apt to crack, and it would have to be looked to very frequently.

6884. And the sewage would go down to the underdrains exactly as it came on the farm?—Yes; and I was engaged to examine the Harrogate Corporation effluent in that way, because there is a place called Knaresborough, a few miles below, where they have to pump the water from the River Nidd there.

6885. What are the advantages of underdraining?—Excess of liquid that would remain in the land is better in some way to be abstracted, but to do it thoroughly in a devised way, and certainly look at the proportion of your drainage to the nature of the land. I like always to command an effluent, something that we can see the result at the works.

6886. With regard to the land available and used for irrigation, of the filtered effluent at Hampton, have you any remark to make on the apparent deterioration of the effluent by being irrigated on land?—When I saw Dr. Cassal's analyses and his note, which is given in my appendix, I took the liberty of inquiring, as he says that it illustrates that land, as far as we can see (he puts it so far a little advisedly) that land deteriorates the effluent, they get from three of each 4ft. deep bacterial tanks there on the Dibdin system. Well, I could not believe it any more than I think you did yourself, General, and I find the same remarks apply at Carshalton, where Mr. Baldwin Latham carried out the works, where it will be seen that the effluent by Mr. Dibdin's analyses apparently is deteriorated by being passed through land, and better without the intervention of land, less albuminoid ammonia. I had occasion to go to Hampton, and I have seen it, I daresay, half-a-dozen times. Circumstances put me in the way available for inspecting it now and again, and I took an interest in following it up a little, particularly as there are 12ft. total depth of tanks. I spoke to the surveyor about how can it be the land gravel when it is of so clean a description. You might have made the Dibdin tanks with such a thoroughly good gravel—full of sand and gritty, no clay matters even to give it discoloration, far less to add to the organic matter. When I named it to him he said, "We have considered it, and find that we put crude sewage a week or a few days before Dr. Cassal took his analysis. We put somewhat crude sewage on the land from the first tank (4ft. above the land there). We put the crude sewage there, and our drain trenches had been only recently filled in somewhat loosely, not consolidated, over the general drainage." In this case, General Carey, too much of it drainage and too shallow, perhaps better there in parts without it, as chiefly open free gravel throughout the 20 acres. In the first instance the crude sewage—practically often thick crude sewage—gathers on the top of the first tank to about three or four inches in depth, recently, I could see. Well, this first tank rough effluent was applied over these trenches, and readily got down to the drains. Then in a few days or within a week afterwards the best effluent practicable to be got from the three tanks was applied over these raw trenches, which had been fouled by the sewage, and the drains also admittedly fouled. The result, of course, was not satisfactory, and organic matter was added to the analyses. This was the explanation as to the deterioration, and now relieving land from having been blamed for it. The same at Carshalton, land not being clean. Dr. Rideal and Mr. Dibdin I saw alluded to these misconceptions.

6887. As to the tidal outfalls, if crude sewage is discharged into the sea or tidal rivers, is it not probable that the solid matter in suspension will be deposited on the foreshore unless there are precautions for discharging it on the ebb, if that is the most favourable current for treating it?—Did you say, General, into the sea or tidal waters?

6888. I said either?—Either? Well, my opinion is, as a rule crude sewage may be discharged at extreme low water mark into the sea without preliminary treatment, but in a direction found by float experiments, as done by me, near Saltburn-on-Sea, for instance, with the approval of the Local Government Board, and since verified satisfactorily, and never any complaint; no seagulls seen over outfall, and no reflux sewage on the beach; but we take it down about 800 yards by metal pipe to extreme low water.

6889. They discharge on the ebb?—On the ebb? No, any time.

6890. Any time?—Into the open sea, and no complaint made of it. Scarborough the same, also Bournemouth. I was down there, and saw the Borough Engineer, and he said no trouble. On the other hand, again, I recently went to look at Cromer, saw there the septic tanks were intercepting or beginning to partly intercept, as they were just about completing three of them—I do not know with what result—to intercept solid matters, at all events, before discharge into the sea. The sewage was to be taken down to low water, or nearly so, but having this preliminary treatment there. I asked the reason why, and they say having a northern aspect there, others and different with east or southern aspect. Having north aspect, and tide coming from the north, they think it necessitates under circumstances like that preliminary treatment. They have had difficulty with visitors observing that floating matters were seen on the shore, and also a great number of seagulls at the outfall, which was, I think, originally within low water mark, not out to it, as ought to be in all cases, and at any rate to have given a fair chance. Then they say that by desire of the Local Government Board at Morecambe Bay preliminary treatment is required, and there it is being carried out. I do not know if the Local Government Board specify the nature of the treatment. However, they have also there a septic tank being constructed. The works have just begun.

6891. In that case the pipe went a very long way out to sea and discharged on the ebb tide. It was proved by floating experiments that by no possible means could it come back to the foreshore. I am now taking an ordinary seaside place. If crude sewage is discharged at all times of the tide is it not probable that the sewage will oscillate backwards and forwards with the tide in front of this seaside place—it may be a watering place or may not?—I think it is a matter that should be very carefully considered, especially a sea resort where any dissatisfaction that way might lead financially to bad results. I think it is a very important point to consider always, and if they are not able to pay to have it taken in tanks and, as you indicate, General, discharged on the ebb tibe only, the same as we do on tidal rivers, as a rule, discharge on the ebb tide, and have it held up there in storage tanks previously.

6892. You have never had any experience of a case where the oyster industry is concerned? Sewage effluent has to pass over oyster beds?—No. I was asked recently on the point so far by some landowners somewhat adjoining to oyster beds. I was there going to give the matter a special consideration, but I have not had actual experience in it.

6893. (*Mr. Killick.*) You mentioned in Northumberland and Durham the County Councils taking notes of

the effluents in those two counties. Do the County Councils supervise all the effluents?—Not yet so much Northumberland, but Durham does. Northumberland does it partly, but the treatment of sewage has not so much been urgent there, the population being more in the County of Durham; but the County Council in such cases are like the West Riding inspectors—very much on the alert, and prosecute and altogether supervise matters very well, I think, and there they take samples of effluent, and have a special inspector, so far similar to those of the West Riding, who chiefly examines sewage works, and reports quarterly, like what I see Mr. Tatton organises for the Mersey and Irwell districts.

6894. Do you know the tests by which they pass such effluents?—They usually when they are unsatisfactory send the analyses, but I think it is chemical analysis and sometimes bacteriological.

6895. Do you know the standards—Yes, that they take the West Riding standard of albuminoid ammonia—that is, 0·1 grain per gallon, not to be exceeded, and for 1·0 grain per gallon oxygen absorbed in four hours.

6896. That is both Durham and Northumberland?—Both Durham and Northumberland, yes, but more particularly Durham, where they have given more consideration as yet, having more scope from population.

6897. Have you any experience of treating the sewage of towns discharging into tidal rivers such as Warrington on the Mersey or Preston on the Ribble?—Well, I got out a scheme for discharging sewage into the River Wear below Durham, but on the tidal portion, the lower reach of it, and there we submitted to the Local Government Board a tank to hold up the sewage and discharge it when the ebb tide was beginning.

6898. Not to treat it in any way?—Well, in conjunction with it there was a subsidence tank, and also an arrangement for adding alumina ferric should it be required.

6898*. Do you think that is sufficient?—For the standard volumes usually taken—viz., the maximum of sewage and the minimum of the river flow at perhaps 30, 40, or 50 times—I think then it is.

6899. But if the river was 30, 40, or 50 times the maximum flow of the sewage sedimentation, is all that is required on a tidal river?—That is my opinion, yes.

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6900. (*Chairman.*) I should like to ask you one general question, Mr. Balfour: Do you think from your experience that the filtration really depends on the quantity of filtration, so to speak,—that is to say that, supposing an effluent has filtered over land and filtered through artificial filters, you would get it equally good, provided the amount of the filtration was the same?—I do not think I quite follow you, my lord.

6901. Well, you can have an effluent filtered through land?—Yes.

6902. And you can have the same effluent filtered through coke or any other artificial filter?—Yes.

6903. Well, do you think, provided the amount of filtration is the same, you will turn out an equally good effluent?—Yes, I quite think so.

6904. Then it depends on the amount of filtration?—Yes.

6905. And not on the quality of the filter?—That is what I think, only giving the bacteria due predominance.

6906. You will be inclined to think that?—Oh, yes, that is really what I come up to. I was a little like others at first, inclined to pooh-pooh the electric light and to pooh-pooh the bacteria tank system a little, but now I think really it can be made effective in that way if not overburdened. I should not exceed, as a rule, over 200 to 150 gallons to the square yard, and it would depend on the nature of the sewage.

6907. (*Major-General Carey.*) That is continuous filtration?—That is continuous filtration, yes. That is my opinion, if I may add that, after looking well into the process, I understand Leeds is also going into continuous filtration. I have seen Leeds and Manchester works on various occasions. Perhaps in conclusion, my lord, you would allow me to say that if you could see your way to take up the subject separately of dealing with domestic sewage, apart from cases where trade effluents are involved, it would be a great relief to many communities? For instance, I am dealing with one where if it were the case of land not being necessary and weak sewage, then we should have no pumping from and no land necessary with, say, a population of about 6,000, save about £4,000 if, as we were just alluding to, the treatment through bacterial tanks would be accepted for cases of weak and domestic sewage only, and leaving your lordship and gentlemen to consider as to trade effluents further on.

TWENTY-SEVENTH DAY.

AT REIGATE.

Tuesday, 27th November. 1900.

PRESENT:

Sir MICHAEL FOSTER, M.P., F.R.S. (in the Chair).

Major-Gen. CONSTANTINE PHIPPS CAREY. | Colonel THOMAS WALTER HARDING.

Mr. F. J. WILLIS, *Secretary.*

Mr. WILLIAM HENRY PRESCOTT (Borough Engineer to the Corporation of Reigate, Surrey), called; and Examined.

6908. (*Chairman.*) You are the engineer to the Sewage Works here?—Yes.

6909. Will you briefly state the history of the present installation?—The trial plant which you inspected this morning was put down at the end of 1898, and consists of a grit tank and two bacteria beds; the grit tank has been designed to hold about two and a half——

6910. Excuse me, the experiment, if we may so call it, arose from a desire on the part of the Town Council to see if there was some other plant of sewage disposal which would be more convenient for the Council than the land system, which would be less expensive and more effective, and your Council determined, after some consideration, to make an experiment with a portion of the sewage?—Yes.

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6911. When were those experiments begun?—The experiments were commenced at the end of 1898.

6912. And in their first form they consisted in diverting a part of the sewage first into a small tank?—That is so—a volume of 20,000 gallons a day.

6913. And then from the small tank into what was called at the time, I believe, an anaerobic sludge bed?—Yes, that is so—an anaerobic bacteria bed.

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6914. And from the anaerobic sludge bed the effluent was carried to what?—To a sprinkler bed, where the final purification was effected.

6915. Was that Mr. Candy's sprinkler then?—On the last bed, yes, sir; the same sprinkler which you have seen to-day; that has never been removed; it has been in operation now for two years.

6916. What was the volume of sewage that you dealt with for this experimental purpose?—Per square yard?

6917. No; how much per day or per hour?—The total volume of sewage dealt with on the trial plant was from 20,000 to 25,000 gallons.

6918. Per 24 hours?—Per day of 24 hours, yes.

6919. Now, will you just briefly describe how that was treated. In the first instance, when you began, it was carried by the conduit to this small grit tank?—To this small grit tank where the road grit and mineral matter was arrested.

6920. What was the size of that tank?—I have not the dimensions of that tank, sir, but it was designed to hold two and a half hours' flow.

6921. Then that was admitted?—Then that was admitted into the anaerobic chamber.

6922. And how was it admitted into the chamber?—It was admitted into the chamber by wooden troughs placed about two feet apart; I should say there were about fourteen in all covering the whole area of the anaerobic chamber.

6923. The anaerobic chamber consisted of a space filled with coarse clinkers or broken bricks?—Coarse clinkers and broken bricks combined, yes.

6924. And was covered over?—And was covered over with clay and with about three inches of turf to prevent the clay from cracking in the summer time.

6925. And what was the nature of the entrance and exit into the anaerobic chamber?—There is a channel there about 18 inches wide and some six inches deep, which admitted the crude sewage into the wooden troughs which I have already described placed about 18 inches apart, and the exit was by means of a concrete sill delivering into a vertical pipe which discharged the anaerobic effluent on to the sprinkler bed.

6926. But that was so arranged, was it not, that the whole of the chamber was waterlogged?—Was worked under waterlogged conditions as regards the anaerobic bed.

6927. From thence it was carried to the chamber with the intermittent sprinkler?—That is so.

6928. What was the nature of the contents of that chamber?—Well, I am perhaps wrong in stating that that was so at the time, if you refer to the chamber intermediate between the two beds the chamber which you have seen this morning occupying the space between the anaerobic chamber, and the final filter bed was not constructed at that time, the anaerobic effluent was then delivered direct on to the sprinkler, there was no intermediate chamber.

6929. But it was delivered in such a fashion that the anaerobic chamber was always waterlogged?—Was always waterlogged; yes.

6930. And it was delivered at the top level of the chamber?—That is so, and the sprinkler bed was worked continuously by that means.

6931. What was the construction of that filter bed at the beginning?—It has never varied from what you have seen this morning; the final filter bed has never been altered in the least.

6932. Can you, or shall we ask Mr. Candy subsequently to, give us a statement?—Mr. Candy has the statement of the filtering material used there; it has never been changed from the time it was put down two years ago.

6933. And the sprinkler was in the form in which it exists now?—That is so, it has never been touched.

6934. In fact the whole of that filter bed remains untouched?—Precisely.

6935. From the time at which it was first installed two years ago?—That is so; it has never been altered in the least.

6936. Then may I ask what led to the changes in the system which have been subsequently introduced?—Well, the anaerobic chamber, although it gave us a very good effluent as proved by the analyses of the medical officer of health, evolved an objectionable smell which might have been taken objection to by the golfers using the common adjoining, and the Council then decided on my recommendation to convert it into a Dibdin bed, and that was done, and as you have noticed this morning, we have the tannery refuse to deal with, and when the sewage was highly charged with this tannery refuse and working on the Dibdin principle, although we gave the sewage as much as six hours contact in the Dibdin bed, that was the coarse bed, the first bed, it failed to remove the colour of the tan and also produced a slight smell. Mr. Candy then suggested that that could be overcome by putting down a sprinkler on the first bed, which was done, and I am pleased to say that it has removed the difficulty. Although some fifteen minutes only elapses from the time the sewage is discharged on the bed to the time it leaves, the colour is entirely removed, and there is practically no smell, as you have seen this morning, and the effluent is all that we could desire. I have the reports which have been presented to the Council from time to time by the medical officer of health; I shall have pleasure in handing them in.

6937. (*Colonel Harding.*) If we could have a typical series of analyses or an average over a considerable period?—I should be very pleased to make you copies of this and send them to you.

6938. We do not want extensive tables?—They are not extensive tables at all; in fact the medical officer since we put a sprinkler on the first bed states in his report that he is of opinion that the effluent from the first bed is fit to discharge into the stream without any further treatment whatever; he is very highly delighted with the result.

6939. (*Chairman.*) The smell that gave offence to the golfers?—We have had no complaint from the golfers, but we were afraid.

6940. You had no actual complaint?—We had no actual complain; no complaint whatever, but the chairman of the Sewage Farms Committee and myself were down there at certain times.

6941. But the odour which was so perceptible arose while your first tank was completely covered over?—That is so, and worked under waterlogged conditions, it gave us a very good effluent, but it evolved this objectionable smell.

6942. How did it evolve it; backwards or forwards, so to speak?—Backwards on the level of the sewer, and I may say too, with a view to overcoming that smell, we covered the chamber in where the effluent was discharged on to the second bed and put some upright pipes, then the smell was emitted on the level of the surface filter—the final bed.

6943. The sewage with which you were dealing was drawn off from the main outfall by a lateral opening?—That is so. There is a 6in. pipe which is controlled by a disc valve.

6944. Consequently, I suppose, a good deal of the solid matter which is in the general outfall is carried past that opening, and it is chiefly the most fluid parts which enter by that valve; but the sewage which you are treating consists of less solid matter probably than the main?—Well, I hardly think that is so; the screens certainly separate the coarser particles of sewage.

6945. Lumps of faeces and so on which would pass your screen would naturally be carried past that opening rather than be drained into it; is not that the effect of a lateral opening of that kind?—I think as you saw this morning there is a lot of faeces in the grit tank.

6946. You think the sewage you are treating is a fair specimen of the general outfall if it has passed the screen?—Yes, I am sure it is.

6947. Then that small tank, what shall we call it—the precipitation tank?—The detritus chamber.

6948. The detritus chamber; that is cleared out at intervals?—Yes, about once every three months.

6949. Can you state roughly how much solid matter there is?—I should think about five tons is discharged every three months.

6950. Five tons?—I should say so.

6951. Of sludge?—Yes, sludge and road grit and mineral matter; that is approximately of course.

6952. Then the final effluent from your filter chamber apparently is taken off in two ways; there is a continuous flow from some depth from the bottom?—Yes.

6953. And the bottom layers which contain a good deal of subsided matter are let off at intervals?—That is so, yes.

6954. The former effluent is discharged on to the land eventually?—True, yes, although it is of sufficient purity to go direct into the stream.

6955. You will let us have some condensed statements of the analyses of the crude sewage; what can you give us?—I can hand in the reports of the medical officer which he has presented to the Council from time to time, in which he gives analyses of the crude sewage and the effluent.

6956. Is there any short abstract of that, any condensed report of that which could be given to us to show in the first place the crude sewage as it is reaching this experimental work, then the fluid which leaves your detritus chamber?—No, I am afraid we have not the analyses of the medical officer of the fluid which leaves the detritus chamber; they have been taken at three points, that is, the point at which it enters the detritus chamber, the point at which it leaves the anaerobic chamber, and the final effluent.

6957. You have no analyses or observations on the nature of the material as it escapes from the detritus chamber?—No, none from the medical officer; I think Mr. Candy has some.

6958. (*Colonel Harding.*) Is your system of sewers here the combined or the separate?—Separate. We have the duplicate system of sewers; we have one set of sewers for the surface water and another set of sewers for carrying the foul water sewage.

6959. Then it is the separate system?—It is the separate system, yes.

6960. And your sewage is, therefore, concentrated by it?—That is so. Also we have two breweries here and a tannery; fellmongers' trade refuse liquors as well.

6961. Is the proportion of the volume of effluents coming from those tanneries a large one relatively to the volume of the domestic sewage?—I think so, yes. The refuse from these tanneries discharges into the public sewers, I should say, about four times a week, and it gives a great amount of trouble on the precipitation works and farm, because it is most vile stuff to deal with.

6962. You told Sir Michael Foster that the material of your second bed had not been changed from the beginning of the experiments?—No, it has never been touched.

6963. Does the same observation apply to the first bed?—That is so, only in this way: that the capacity of the bed has been reduced; originally we worked the bed under anaerobic conditions.

6964. Then you have not changed the material?—No.

6965. Nor disturbed it at all?—Not in the least.

6966. You used it at first as an anaerobic bed perfectly full?—That is so.

6967. And after without changing the material you arranged to empty it and then to work it on the continuous principle?—Quite so; that is so. *Mr. W. H. Prescott.* 27 Nov. 1900.

6968. Did you go through any process of cleansing or washing of it at all?—No, not in the least. In fact, when the cover was taken off the anaerobic chamber I got the man you saw there this morning to dig down with the spade, and he found it perfectly clean.

6969. How long had it worked as an anaerobic bed?—I should say from nine to twelve months.

6970. And you never found occasion to remove anything from it?—Nothing whatever.

6971. Was there any valve to permit of anything being removed?—Yes, there is a valve there.

6972. Was it used to remove anything at any time?—There was a valve in the chamber by means of which we could flush it, but we never used it.

6973. As matter of fact, you never did flush it?—No.

6974. And you never removed anything from it?—No.

6975. You found no accumulation at the end of twelve months?—No. When the man dug down with his spade we were surprised to find it so clean.

6976. Your only desire to change the system was the smell arising from it?—That is so; it evolved a bad smell, and we thought it desirable to do that.

6977. If you could give us a typical analysis of the old system that worked anaerobically, and the new system that worked as a continuous filter, we shall be glad to have it. You can hand it in?—I will hand them in. I have got the analyses of the medical officer when it was worked under anaerobic conditions, and also when we had the Dibdin contact bed and the sprinkler bed as it is now.

(Copy.)

17, Spencer Park,
Wandsworth Common,
London, S.W.,
May 17th, 1899.

To the Reigate Urban Sewage Farm Committee.

Gentlemen,—I have examined a sample of the crude sewage, a sample of the effluent from the anaerobic bed, and a sample of the effluent from the anaerobic filter at your Earlswood Sewage Farm, which your surveyor sent me on May 13th, and have set out some of the analytical data below, together with some remarks upon the results of the examination.

Yours obediently,
(Signed) E. L. Jacob.

	Crude Sewage.	Effluent from Anaerobic bed.	Effluent from Aerobic filter.
Appearance	Very turbid, with much flocculent sediment.	Turbid, with some flocculent sediment.	Fairly clear, on standing, deposited scarcely any sediment.
Odour	Of sewage	Of sewage	None.
Combined Chlorine (grains per gallon).	6·3	5·75	5·25
Oxygen required to oxidise dissolved organic matter (grains per gallon).	1·2	2·2	0·75
Free and Saline Ammonia (parts per million).	60·0	60·0	30·0
Albuminoid (Organic) Ammonia (parts per million).	Not determined owing to an accident.	1·95	0·30
Remarks	This is a sample of a sewage of medium strength.	The sample was very fairly free from suspended matter, and as might be expected, contained more dissolved organic matter than the crude sewage, as determined by the "oxygen process."	The sample was so free from suspended matter, from odour, and from organic matter, as determined by the "oxygen process," and by the "ammonia process," as to be quite fit to discharge into the brook without further treatment.

Mr. W. H. Prescott.

27 Nov. 1900.

(Copy.)

17, Spencer Park,
Wandsworth Common,
London, S.W.,
October 18th, 1899.

To the Reigate Urban Sewage Farm Committee.

Gentlemen,—I beg to submit the following report upon three samples which I received from your surveyor on the 16th inst.:—

1. Sample of crude sewage, taken at 10.30 a.m. on October 14th, on its way to the experimental coarse bacteria bed. The sample was turbid and of a deep brown colour, and on standing deposited a considerable reddish brown sediment. It had the odour of sewage and of tan, and contained a very large quantity of organic matter in solution, the amount of oxygen absorbed from potassic permanganate being 20 grs. per gallon, or about eight times as much as was absorbed from previous samples of the Earlswood crude sewage. This of course shows that this sewage would be much more difficult to purify and break up into inorganic salts than ordinary sewage, especially if the organic matter in it, as I am informed, was chiefly of vegetable origin (spent tan.)

2. Sample of the effluent from the coarse bed, taken at 1 p.m. This sample was also turbid and brown, but on standing, only deposited a small quantity of brown sediment. It smelt faintly of sewage and tan, and contained much less dissolved organic matter than the crude sewage, the quantity of oxygen absorbed from potassic permanganate, though still very great (viz., six grains per gallon), being less than a third of that absorbed by the crude sewage.

3. Sample of the effluent from the fine bacteria bed (aerobic) taken at 1.20 p.m. This sample was slightly turbid, and threw down only some slight grey sediment on standing. It was nearly colourless, and it had a slight earthy smell. The amount of dissolved organic matter was greater than in previous samples of this final effluent (the "oxygen absorbed" being two grains per gallon, and the albuminoid ammonia being two parts per million or ·14 grains per gallon), and was also greater than would be considered right and proper for a final sewage effluent. As the sample was taken only twenty minutes after the effluent from the coarse bed, it does not represent what changes had been effected on that effluent in the fine bed, but if the two were really comparable, then it shows that a very great purification had been effected by its passage through the fine bed.

Yours obediently,
(Signed) E. L. Jacob.

Note.—During this month the coarse bed was working as a Dibdin or Sutton contact bed. No. 3 sample is absolutely comparable with No. 2.

(Copy.)

17, Spencer Park,
Wandsworth Common,
London, S.W.,
July 19th, 1899.

Dear Sir,—Your samples of crude sewage and of sewage effluents were delivered here on Tuesday (yesterday) morning, which happened to be a rather inconvenient time, for Dr. Williamson is away on his holiday, and I was extremely busy yesterday and to-day. I have, however, examined them as far as the short time at my disposal has permitted (for you want to receive my report to-morrow), and I have to report as follows:—

The crude sewage contained more ammonia and dissolved organic matter than the sample sent me on May 13th, and was, in fact, a rather stronger sample of domestic sewage than the other.

The sample of effluent from the anaerobic bed was much more turbid and threw down a larger quantity of suspended matter than the previous sample in May, and was in that respect, and to that extent, not so satisfactory as before.

The sample of effluent from the anaerobic bed was not quite so free from suspended matter as was the previous sample in May, but it must nevertheless be considered to be quite satisfactory, for it had no odour on its arrival here, and has not since developed any, and it did not contain more organic or other oxidisable matter than may properly be allowed in a sewage effluent on its way to a small stream not used by man for drinking purposes.

Some of the analytical data are set out below.

Yours faithfully,
(Signed) E. L. Jacob.

	Crude Sewage.	Effluent from Anaerobic Bed.	Effluent from Aerobic Bed.
Appearance	Very turbid, with copious black sediment.	Turbid, with a good deal of black sediment.	On standing, threw down a perceptible dark sediment. On agitation, rather frothy.
Odour	Very strongly of sewage	Of sewage	None.
Chlorine, as Chlorides	6½ grains per gallon	9 grains per gallon	7½ grains per gallon.
Oxygen required to oxidise organic matter, &c.	2·7 grains per gallon	1·36 grains per gallon	·80 grains per gallon.
Free Ammonia	100 parts per million	80 parts per million	40 parts per million.

(Copy.)

17, Spencer Park,
Wandsworth Common,
London, S.W.,
February 14th, 1900.

To the Reigate Sewage Farm Committee.

Gentlemen,—I have examined some samples which your surveyor sent me from your sewage farm on February 9th, with the following results:—

A sample of crude sewage.—This liquid was of a dark brown colour, and, on standing, deposited a copious dark sediment. It smelt slightly of tan water, and did not develop any offensive odour; it was chiefly the refuse from the tanyard, I should think.

A sample from the coarse filter bed on to which the crude sewage is delivered.—This liquid was almost colourless, had no smell, and was only slightly turbid, depositing a slight sediment on standing. It contained very little organic matter, and was quite fit to discharge into the brook adjoining the farm. It was taken only a quarter of an hour after the sample of crude sewage, but your surveyor assures me that it represents quite fairly what had been done to the brown crude sewage by passing it through the coarse bed, and, if that is so, the result is very satisfactory, especially in the complete decolorisation of the liquid which had been effected.

A sample of the effluent from the fine grain filter.—This was still better, if possible, than the preceding sample, as it was even more free from suspended matter, and contained less organic matter, than the other.

Yours obediently,
(Signed) E. L. Jacob.

6978. What is the total volume of your sewage?—1,250,000 gallons dry weather flow per 24 hours.

6979. In wet weather it does not vary very materially,

as the surface water is treated in another way?—Sub-soil water gets into the sewers in wet weather.

6980. What becomes of your surface water which goes down your streets?—We take it in the streams.

6981. Do you not find after dry weather the first washing of the roads is very foul?—There is no doubt about it.

6982. And it ought to have treatment. Does the river authority allow you to let such surface waters go into the stream without treatment?—Yes, we have had no objections from them at all.

6983. (*Chairman.*) The detritus tanks remains now exactly as it was when it was first installed?—Precisely the same. It has never been altered in the least. Only I should say that originally we had two screens there, and we found them to be unnecessary, so we took them away. That accounts for those grooves at the bottom of the chamber which you noticed this morning.

6983*. (*Major-General Carey.*) When the detritus tank is emptied it is nearly full of sludge, I suppose?—No; I should say it is about half full.

6984. Then does the action remain the same? The solid matter, is it intercepted to the same extent as it was before, when it was started?—Well, of course, it may not be, because when there is no solid matter at all in the tank it holds two and a half hours' flow, and probably it will not be rested to the same extent, though I should not imagine there is very much difference.

6985. There is not much difference between starting and the end of the three months when you went in?—I should not think so, because we do not find the capacity of the first bed to be reduced at all; it does not injure the first bed. For that reason I imagine there is very little difference, if any. May I be allowed to hand in a copy of a report which I presented to the Town Council just recently, dated September?

6986. What is the nature of the report?—It is dealing with converting the existing precipitation works to this principle, and also dealing with the trial plant from its inception in 1898, and detailing the results from that time to the present day.

Engineer's and Surveyor's Office,
Town Hall, Redhill, Surrey,
September, 1900.

To the Chairman and Members of the Sewage Farm Committee.

Gentlemen,—I beg to present my report on the bacteriological sewage purification trials carried out at the borough sewage works and my recommendations based on such trials, as to work required to be executed to put the existing works into the condition you desire them to be. I would first of all recall to your mind that previous to the construction of the trial plant you examined by deputation the then existing processes of bacteriological sewage purification, and it was ultimately decided on my recommendation to test the sprinkler system as the one that appeared to promise best. The trial plant was put down at the end of 1898; I have carefully watched its working, and the process has been most thoroughly and exhaustively tested. The plant, as you know, consists of a preliminary detritus chamber or catch pit, holding about two hours' flow of the sewage treated, this catch pit having a scum board, but no screen. The sewage is delivered into the catch pit through a gauge board, and is taken from the main sewer previous to any chemical treatment. The bacteria beds are two in number, and so placed that the sewage passes first through one and then through the other. The first bed is 21ft. square, and the second bed is 24ft. diameter, and contains a layer of polarite.

The second bed has always been used as a sprinkler bed, but the first bed was so constructed that we could carry out a series of tests as to what was the best "first treatment" for the sewage previous to its final purification through the sprinkler bed. The first bed was originally arranged to work as a closed "anaerobic or septic" bed, in which the solids should be, as far as possible, disposed of by liquefaction, and in this way the bed was worked for about nine months. The final effluent—*i.e.*, after passing through the secondary or sprinkler bed—was always entirely satisfactory, and the working of the anaerobic or septic bed itself was satisfactory except on the one point to which I will shortly refer. I must here digress somewhat to point out that the Reigate sewage is one of exceptional strength and foulness, and contains, as you know, large quantities of tannery refuse and also of brewery refuse. *Mr. W. H. Prescott.* 27 Nov. 1900.

The great strength of the sewage was doubtless the cause of the objection found to the anaerobic or septic treatment, viz., the smell from the half-treated liquid. Had the sewage been a weak one it is probable that the smell would have been practically imperceptible, but with a strong sewage such as the one we have to deal with septic treatment is, I am convinced, inadmissible.

It was therefore decided to test the working of the "Dibdin or holding up" process on the first bed to see if by that means we should overcome the objection named. I accordingly had the bed altered to the requirements of the Dibdin method, and worked in that way for several months. The results were disappointing. There certainly was but little smell, and often there was no smell, but the purification effected was practically nil, especially upon the tan sewage, although the Dibdin bed was not dealing with more than a quarter of the sewage that the bed had previously dealt with. The Dibdin method also involved frequent manual attention which was not before required, and, moreover, there was a distinct tendency of the bed to clog. Neither of these "first treatments" having proved equal to your requirements, I decided with your permission to test the first bed as a "sprinkler bed," which was accomplished by removing some of the material and placing a sprinkler on the bed, the sprinkler being connected with the supply channel from the catch pit by means of an automatic feed. I am pleased to report to you that this method has proved entirely successful, as not only is there no smell, but the effluent is better than by either of the other methods—indeed, so good is the effluent that Dr. Jacob (Medical Officer of Health) is most surprised at its purity. His report is herewith given:—

17, Spencer Park,
Wandsworth Common,
London, S.W.,
February 14th, 1900.

To the Reigate Sewage Farm Committee.

Gentlemen,—I have examined some samples which your surveyor sent me from your sewage farm on February 9th, with the following results:—

1. A sample of crude sewage. This liquid was of a dark brown colour, and, on standing, deposited a copious dark sediment. It smelt slightly of tan water, and did not develop any offensive odour. It was chiefly the refuse from the tanyard, I should think.

2. A sample of the coarse filter bed, on to which the crude sewage is delivered. This liquid was almost colourless, had no smell, and was only slightly turbid, depositing a light sediment on standing. It contained very little organic matter, and was quite fit to discharge into the brook adjoining the farm. It was taken only a quarter of an hour after the sample of crude sewage, but your surveyor assures me that it represents quite fairly what had been done to the brown crude sewage by passing it through the coarse bed, and, if that is so, the result is very satisfactory, especially in the complete decolorisation of the liquid which had been effected.

3. A sample of the effluent from the fine grain filter. This was still better, if possible, than the preceding samples, as it was even more free from suspended matter, and contained less organic matter than the other.

Yours obediently,
(Signed) E. L. Jacob.

I find that fish will live in the effluent, and there have been fish living in it for some considerable time past. This is eminently satisfactory, as it shows that in addition to being chemically pure, the effluent contains large quantities of dissolved oxygen. It may interest you to have an opportunity of reading a report by Drs. Kenward and Butler, of University College, London, upon this point. I therefore give it below.

Drs. Kenward and Butler, of University College, London, have examined the effluents from the Reigate sprinkler bed, and their report, as follows, will, the writer feels sure, be read with the greatest interest:—

"The object of our series of experiments was to ascertain whether the amount of dissolved oxygen in

Mr. W. H. Prescott. 27 Nov. 1901.

the effluent from an anaerobic bed, constantly fed by the revolving sprinkler devised by Mr. Candy, differed materially from that in the effluent obtained from the same bed worked by the methods commonly in use.

. . . . . .

"The samples were all collected so that they entirely filled the bottles, and they were analysed on the day on which they were collected."

"Those effluents from the anaerobic bed which were examined were found to contain no dissolved oxygen."

"Three samples, taken on different days from the anaerobic bed constantly fed by the anaerobic effluent by the sprinklers, were found to possess dissolved oxygen varying from 4·5 to 7·5 milligrammes of oxygen per litre."

"When, however, the discharge from the outlet pipe was stopped, and the anaerobic bed was then filled by the sprinkler and allowed to stand full for two hours, the effluent which came away contained dissolved oxygen amounting to only about one milligramme per litre—an amount almost identical to that found when the bed was filled up without the sprinkler."

"The value of the method adopted for treating the bed with the sprinkler appears, therefore, to be as follows:—In its fall from the sprinkler to the surface of the filter bed the effluent absorbs a barely appreciable amount of oxygen, so that the high figure of dissolved oxygen found in the effluent as it emerges from the bed is doubtless due to the manner of its distribution in its passage through the filter.

"The descending effluent arranged in spiral films alternating with layers of air constitute an arrangement admirably adapted to ensure thorough aeration not of the effluent only, but of the filter bed itself.

"It is doubtless due to this that the dissolved oxygen frequently equals that found in samples of good drinking water."

I have now satisfied myself that with the sprinkler system there is no tendency of the beds to become clogged, as is the case with the Dibdin beds—in fact, the sprinkler beds are self-cleansing; whatever goes on to the bed comes away from it, and this must be the case if a bed is to have anything but a limited life, as any permanent retention of matter in a bed will infallibly result sooner or later in the choking of the bed. Matter cannot be destroyed, its character can be only changed. In the case of the liquid from the sprinkler bed, the complex putrescible compounds of the organic matter has been entirely changed into innocuous and more simple combinations. Experience has proved that a little solid matter is always produced from bacterial beds, and it is of the utmost importance that this "burnt-out ash," as it is termed, should not be retained in the bed, but should be discharged with the effluent, from which it can be easily removed by settlement. This condition the sprinkler beds comply with. The surface of the sprinkler bed has not required to be cleansed or dug up or in any way to have manual labour expended upon it. The "burnt-out ash" before referred to constitutes (together with, of course, the grit and such-like mineral and insoluble matter brought down by the sewers) the only solid matter there will be from the treatment, and this can be easily disposed of by running it into trenches in the land, being an oxidised product, the burnt-out ash being, of course, very different from sewage sludge. I find that frost has no detrimental action on the working of the beds.

My recommendation to your committee as the outcome of these critical trials are that you should adopt the system of "double anaerobic sprinkler bacterial beds," preceded by preliminary treatment of the sewage in a suitable catch pit or detritus tank. I would suggest that the existing precipitation tanks be utilised, the first tank to be arranged as a catch pit, dividing it into two parts for cleaning purposes, the other five tanks to be converted into coarse filter beds, fitted with three sprinklers, each 79ft. diameter, the present divisional walls being reduced about 1ft. 9in., to allow the sprinklers free passage. The speed of filtration I recommend you to adopt is at the rate of three square yards for every 1,000 gallons of sewage per 24 hours, so that in addition to the area obtained in the existing tanks four additional sprinkler beds of 78ft. diameter, each placed in line with the present tanks, would be required, together with one similar in addition as a stand-by. Thus there would be eight coarse beds of 79ft. and 78ft. diameter. The same number of fine beds would be required. These would be placed below the coarse beds in similar manner to the trial plant, and as shown on larger detailed plans which I have had prepared in my office. The area recommended is a most ample, though not an extravagant, one, and I may state that in the trials the speed of filtration has been considerably greater than the speed upon which I am calculating for the whole scheme. The plans will, I think, together with what has been said, explain themselves to you. They have been prepared to deal with a flow of 1½ million gallons of sewage per 24 hours. As regards the storm water, part of it will be dealt with on the proposed works, part will go on the land, and the remainder will be able to go direct down the storm overflow. The advantages of the scheme I now present to you are both numerous and important. In the first place it will enable you to produce an effluent such as will at all times meet with the approval of the Thames Conservators; secondly, it will enable you to get rid of the odours from the farm which have been the cause of so many complaints; thirdly, it will overcome the sludge difficulty; fourthly, it will be more economical as well as infinitely more efficient. I estimate that by it you will save an expenditure connected with the present tank treatment alone considerably over £1,200 per annum, which at 5 per cent. is equivalent to a capital outlay of £24,000. Then there should occur a considerable saving on the farm, for, as it will be required for use as a purifying agent, better crops should be grown, and much better returns made. The purified effluent also will be in such a condition as to be a valuable fertiliser when required.

In order to test the working of the large sprinklers recommended I would suggest that two large beds, 78ft. diameter, be first constructed at the end of the precipitation tanks, or that you instruct the chairman and myself to visit Leeds to view their works at Newlay, where a 76ft. sprinkler is in operation.

The scheme I submit to you is a most economical one. If any other process were adopted, such, for instance, as the Dibdin beds, the cost without automatic apparatus alone would be about £6,000 more than the sprinkling process. I have no hesitation in affirming that the "sprinkling process" is the only satisfactory one for Reigate, and my conclusions are based on the very exhaustive and critical trials carried out on your own works during the past two years.

I estimate the complete cost for the conversion of the whole system to be £13,000.

I am, gentlemen,

Your obedient servant,

W. H. PRESCOTT,

Borough Surveyor.

6987. (*Colonel Harding.*) Do you estimate therein what would be the likely cost of carrying out on the lines of this recent experiment the necessary works for your whole flow?—Yes, £13,000. That, of course, deals with three times the normal flow, in accordance with recent regulations issued by the Local Government Board.

6988. And at what rate per square yard do you calculate?—333⅓ gallons.

FRANK CANDY, Surveyor and Sanitary Engineer of the International Purification Syndicate, of 109, Victoria Street, London, called; and Examined.

Mr. F. Candy.

6989. (*Chairman.*) Would you kindly state now what part you have taken in this installation?—I was consulted by Mr. Prescott with respect to a biological system. Knowing me as the inventor and producer of chemical precipitants and filtering materials, and as having large experience in the treatment of sewage generally, he desired me on the part of the Council to put down a biological system, and I recommended the system which you saw to-day. The first part of the treatment was originally anaerobic because it occurred to me that there might be places where you could not get sufficient fall to deal with the sewage by a double aeration system. That system, as you have heard from the Borough Engineer, gave satisfactory results, but the Council were afraid that there might be complaint from the gases given off from the anaerobic bed. These gases could have been

dealt with by combustion, but it was desired then to make a change to the contact system as it is known here—the Sutton system.

6990. Under your advice?—No, not under my advice, although I was rather interested to see what would be the result. About a foot of stone above the troughs was taken away, as well as the clay cover, so that the bed became an open one four feet nine inches deep. The bed was then worked on the contact system without that additional foot, as at present, being removed. think I am correct, Mr. Prescott.

(*Mr. Prescott.*) True.

(*Mr. Candy.*) It was not necessary to remove that foot until we employed the sprinkler, when we wanted a fall, so that there was practically the same depth with the contact system that there was with the anaerobic system. I intend giving results; they are tabulated here—analytical results. The contact bed, after three months' working, not being able to remove the brownish tint or colour from the tannery refuse, notwithstanding the small volume dealt with, Mr. Prescott said he would like to see the result of the anaerobic treatment on the first bed by means of a sprinkler, and it was in the early part of December of last year (1899) that the sprinkler was put upon the first bed, and it has been working continuously night and day ever since. There was a small intermission during the period of putting down the sprinkler (probably a week); the sprinkler was on the ground ready to be put in; there was simply a stone placed in the centre of the bed, and the sprinkler bolted down and connected to the intermitter; from the changing over from the contact or Sutton system to the coarse aerobic sprinkler system there may have been a week's stoppage.

6991. Will you state the points concerning this sprinkler, its introduction, and what you think to be its merits. I understand that the sprinkler now in the upper chamber is identical in principle with that in the lower chamber?—It is identical in principle, but the construction is slightly different.

6992. Will you kindly state the points of one sprinkler and the other, and what in your opinion it is that they effect?—I am of opinion that both sprinklers are equally effective, only in the top one on the first or coarse bed, it is more convenient to lay the feed pipe underneath, or on a level with the filtering material and to allow the sewage to rise and deliver through a bell-shaped mouth into the basin, but the results are identically the same. Now in the lower sprinkler, on the second or fine bed, the sewage or the partly treated sewage is delivered by a trough. That necessitates an arrangement of a shaft through the centre of the basin. It is not quite so convenient for construction, but in other respects the principle is identically the same.

6993. Will you kindly state briefly the principle of the sprinkler, and what may be claimed as the effect it produces?—I will be as brief as I can, Sir Michael. I have been connected with sewage treatment for something like 20 years partially, but for 16 years entirely, and I found there was a difficulty of distributing the water over the filter bed equally. I tried to make channels, and also formed the filter-bed surfaces slightly irregular or sloping with a view to get the water over it, for otherwise the water, we found, would scour the filter-bed surfaces into grooves and channels. That has been a difficulty. I also tried an intermittent system of flushing by automatic syphons on to the beds. Finally, I may say my son, with a view to obtaining even distribution, invented this system of automatic sprinkler working at a very low head. He carried out a long series of experiments in Cheshire, and the results were brought to my notice, and acting independently of him, and representing as I did, the International Syndicate, I adopted it as it proved to be the very best method of distributing water or sewage upon a filter bed. And I should say at once that by getting the re-action of the sewage issuing from the pipe sufficiently powerfully to cause that pipe to revolve, we have accomplished and solved the difficulty of distributing water equally over filter beds, no matter whether it be for water or for sewage, and with its application I have every cause to be thoroughly satisfied. The first sprinkler on a large scale was this one put down on the lower or fine bed; it has never been touched; it has never been removed; it costs a little for oil, but it is infinitesimal as you can imagine for oiling the ball-bearings. It works night and day without any difficulty, so that we consider that we have by means of adopting this sprinkler (which is open to any company or individual to purchase) got over the difficulty of distributing the water, and as you know, sir, without distributing equally you cannot expect the bed to work equally. We have attempted it by numerous channels and by flushing and tipping them, and we have got very good results, but not equal to those obtained by the sprinkler, and I consider it a great advance upon anything done up to the present day in the way of distribution.

6994. The revolution of the sprinkler is effected by a small head of water?—The revolution is caused by the re-action of the water issuing from the holes in the pipe, and we find we can reduce that head to even three or four inches. As long as we keep the mouth of the distributing pipe submerged, we get the re-action, and sufficient power.

6995. And by what means is the uniformity of the distribution secured?—By different distances of perforation along the pipes, and also by the size of the perforations. Those vary according to the length of the pipe. They might commence with one-eighth of an inch diameter and extend up to three-quarters of an inch. The number and size of the holes are worked out mechanically in accordance with the number of gallons we want to distribute per square yard based on the maximum quantity required upon any given yard, and whether that yard is close to the centre or at the extremity of the pipe the distribution per square yard is equal.

6996. And the clogging of the holes is prevented by what means?—Upon and in the basin of the coarse bed there is a screen which will prevent any filamentous or large flocculent matter from getting into the holes. The holes will become somewhat interrupted and it is necessary that there should be an attendant to look after it, probably once a day it will take him five minutes to run up a brush on the outside. The clogging matter is easily disturbed because you have the pressure from the inside, which will drive out any material.

6997. How often do you find it necessary to clean out the tubes inside?—

(*Mr. Prescott.*) I should say about once a week.

(*Mr. Candy.*) There is a brush.

(*Mr. Prescott.*) There is a brush and there is an opening made in the wall by which means this brush can be pushed through, and I am told this is done about once a week on the coarse bed. Of course, in the finer bed it is much less.

(*Mr. Candy.*) There is no practical difficulty, and during the 20 degrees of frost last year we had no stoppage in the flow of the sewage through the beds. We took the temperatures during the severe frosts at the mouth of the sewer by the screening chamber where it was 48 degrees; running down the open carrier to the detritus chamber it was 47 degrees; passing through the detritus chamber on to the first bed I think it was 46 degrees or 45 degrees, and it issued finally at 43 degrees from the fine bed. With reference to the material in the second filter bed, that is the oxidising bed, we attach very much importance to the substance which is called polarite. I will show you what it is.

6998. May I ask why you attach importance to that; what is the experience which has led you to attach importance to that?—You obtain a fine porous body, a body of microscopical powers, not cellular like a piece of coke. That is a large lump (handing in a piece of polarite); if you have a little water I will show you the effect.

6999. But is the importance you attach to this material derived on theoretical grounds or from experience?—From long experience. It was an improvement upon Spencer's carbide. Spencer introduced his magnetic porous oxide of iron, but he produced it by introducing foreign matter and by a double process. We produce polarite by a single process, and we claim that there are no impurities in polarite.

7000. You say that?—Well, I am the inventor; this is my patent (producing the specification), but I work it with some friends, and we formed ourselves into a company—not a public company, it was a private limited undertaking.

7001. It is your material, this polarite?—Yes. Previous to this I had been searching for a material containing impalpable pores, and I found in the Bovey Tracey clay basin of South Devon an amorphous deposit which contains very fine silica so finely divided that it was scarcely perceptible, and we could, by driving off the volatile matters get a very porous material with which we could obtain marvellous results. The difficulty, however, was it broke down; it was so friable. Then I saw that another mineral containing carbonate of iron would not break down, and by driving off the carbonic

Mr. F. Candy. 27 Nov. 1900.

acid we got this microscopic porosity. It is porous in all directions, entirely different to a piece of coke or cinder, in which you get the cells or walls of vitreous matter, whilst in polarite the walls are porous, and the result is wherever this material is used—used according to our instructions—we get the increased advantage.

7002. May I ask, have you experience of a filter bed like that, for instance, that we saw to-day constructed in the absence of polarite with other material?—Not on the fine bed.

7003. Your experience is limited to fine beds in which polarite has been a constituent?—With bacteria beds that is so.

7004. Therefore your experience is not based on a comparison between a filter bed containing polarite and a filter bed not containing polarite?—It is based on 16 years' practical working in regard to filtration generally, and on numerous results obtained in different parts of the country, even in places where sand filters and coke filters and filters of other material have been tried.

7005. Filters on a small scale?—Yes, and some on a fairly large scale. We could get nothing like the results that were obtained without polarite that were obtained where polarite was used. We have a long series of results bearing upon that, sir, and here is one showing a sand filter and also a polarite working side by side. I can hand this in to you; it will do, perhaps, equally well to illustrate my meaning. It is a case in point of a sand filter and a polarite filter worked side by side.

Comparative test of a sand filter and polarite filter made by Mr. J. Carter Bell, A.R.S.M., F.I.C., County Analyst for Cheshire, etc., etc.

Mr. Carter Bell made the following practical test upon the polluted water of the River Irwell, to compare sand filtration with polarite filtration:—

In a filter he placed a quantity of the best Lowestoft sand carefully packed, and in another filter of the same dimensions he placed a layer of six inches of polarite in lieu of the sand.

The water filtered through the Lowestoft sand was found to contain ·35 parts of free ammonia and ·18 parts of albuminoid ammonia per 100,000 parts, whereas the water passed through the filter containing polarite had only ·18 parts of free ammonia and ·07 parts of albumenoid ammonia per 100,000. This was an improvement of nearly 50 per cent. in free ammonia, and more than 60 per cent. in albuminoid ammonia, over the sand filtered water.

The unfiltered Irwell water, which is little better than sewage after precipitation, contained ·46 free ammonia, and ·38 of albuminoid ammonia, per 100,000 parts.

The physical difference between the sand and polarite filtered waters was very striking. The sand filtered water was yellow, though clear, and foamed greatly on shaking; the polarite filtered water gave absolutely no foam whatever on shaking, and was perfectly bright, clear, colourless, and sparkling. In fact, it was perceptibly better in appearance than many drinking waters. Both filters were worked for the same length of time before samples were taken for analysis, and under similar conditions; the polarite filter, however, was running about 25 per cent. faster than the sand filter.

7006. (*Colonel Harding.*) Polarite you have only used in the fine filter here?—That is so.

7007. There is no polarite in the coarse?—That is so.

7008. What amount of purification do you obtain in the coarse filter as measured by the albuminoid ammonia?—We have obtained by means of the sprinkler as much as 80 per cent.

7009. In the coarse filter?—In the coarse filter.

7010. Without polarite?—With polarite we always find the organic matter in solution in sewage is more easily broken down. It is when you get an effluent from the first bed stubborn that you have difficulty in breaking it down through a second bed without such a powerful oxidiser as polarite.

7011. Still we have the fact you have given us that you have found without polarite in the first bed you are able to obtain a very large purification?—Undoubtedly.

7012. And do you seriously suggest that in that fine bed the purification is largely effected by the use of polarite?—That is my experience.

7013. But the amount of polarite used in the fine bed would only represent a layer of about 3ins.?—Of about 3ins., but we have had a layer of an eighth of an inch of polarite in a fine state of division, and we have had 97 per cent. of purification.

7014. It remains to be tried what comparative results would be obtained with and without polarite in the fine filter?—That is so; yes.

7015. But you suggest from your experience that polarite is useful?—Undoubtedly, because you can get a better result with it from a shallow filter than without it from a deep filter. I will take for instance the filter I spoke of at Rodley, there the filter bed is about 12ft. Now I suggest that if we made a filter 3ft. 6ins. deep, and used a layer of polarite, we would get a better result than you would get with a filter 12ft. deep, and a higher speed of filtration—a more rapid degree of filtration—for instead of filtering say 200 gallons we would probably filter 600 gallons per square yard, and get equal or better results.

7016. Well, returning to the sprinkler, what is the head which you find to be practically necessary to work the sprinkler?—Only sufficient to cover the mouth of the sprinkler pipes. If you had the pipe 8ins. in diameter I should like to see the mouths of the pipes well submerged.

7017. It is practical to work with 12in. heads?—Undoubtedly we could never want more unless your delivery pipes were more than 12ins.

7018. Then it would be practical to work the sprinkler continually at the same rate with that head?—Yes. If you could get that head.

7019. At a reduced flow?—If the flow was not sufficient to fill the distributing pipes you could hold it up till you had sufficient flow.

7020. And if you had the holes in the sprinkler reduced working continuously it would give the same flow per diem. Would the same head be sufficient to work it; I should think probably not?—No, I think you may bring down the limit too low. Suppose you had only two holes in each pipe each hole one-eighth of an inch in diameter, and you had a flow of one gallon per minute that would not for a large sprinkler be sufficient to get over the friction.

7021. Do you suggest that the intermittence has, among others, this advantage that you may work with a smaller head?—Yes, where the flow is limited.

7022. Then what other advantages do you claim for the intermittence?—That we avoid the growth upon the surface of the bed, and that growth leads eventually to clogging; all these short intervals of rest, say three minutes out of every four minutes are most beneficial.

7023. The upper part of the bed aerates frequently?—More quickly, and we do not get that growth we get a free current of air constantly passing down.

7024. But we noticed to-day no appreciable intermittence or variation in the flow from the first bed?—Yes.

7025. And therefore the flow becomes equalised as it passes through the bed, and the intermittence probably does not act very far down from the surface?—I have found that in an ordinary sand filter; immediately we place a column of water upon the surface. If that filter had been used within, say twenty-four hours, water commenced to be forced out from the bottom long before the water placed on the surface could have reached the bottom. This is due to water being squeezed out of the lower layers by the compression of the air, so that I contend, sir, it is not due to the fact that the top water must come into contact with that already in the filter, but that it is pressed down and out of the filter by the air. The air pressing the water drives out at the bottom. All the spaces are free and open spaces, and between the material, and thus it is evident that the continuous outflow from the filter is due to atmospheric pressure.

7026. In your second bed you have fine material. Have you considered the advantage, if any, that might arise from the use of coarse material in the second bed instead of fine?—Well, I have considered that, and am of opinion that three-quarters of an inch material for the top of the finer or second bed is quite large enough, sir; that even fairly large suspended matter can freely pass through and become oxidised.

7027. You find that the suspended matter if finely divided does pass through it?—Does freely pass through.

7028. And reaches the bottom of it in the condition of humus?—That is so, sir.

7029. Kindly put in, will you, a typical analysis showing average results over a considerable period?—Yes.

7030. So as to enable us to compare crude sewage with

the effluent from the first and the filtrate from the second?—Yes, during the time the coarse bed was worked anaerobically, and then during the time it was worked with the Sutton system, and during the time it has been worked—the last twelve months with the double aerobic.

7031. If you will be good enough to do so I think that will give us the information we want?——

7032. (*Major-General Carey.*) And an analysis of the effluents from the detritus tank before it passes on to the first filter?—Yes, I will add that sir.

7033. Have you made any experiments with sewage mixed in large volume with trade refuse by this process?—Yes, we did experimentally at Melton Mowbray, where there are large dye works and wool scourers' works, and that led us to full confidence in recommending it as the best method of dealing with manufacturers' refuse, and when Mr. Prescott informed me that they were in a difficulty with this tannery refuse I strongly recommended him to adopt this system for that reason, sir.

REDHILL CAPACITIES.

Bacterial Oxidation Polarite System, with Candy Automatic Revolving Sprinklers and Intermitters.

There are two detritus chambers fitted with deep scum boards, each 8′ × 4′ × 3′ 3″ average depth; these with the channel from gauge weir to intermitter outlet have a capacity of 1,474 gallons.

The flow over the gauge sill to detritus chambers is 10·55 gallons per minute.

Each chamber holds nearly 70 minutes' flow, and the two together nearly 2 hours 20 minutes flow for contact or inoculation and sedimentation; this has been found ample.

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The circular coarse sprinkler bacterial bad is 21ft. diameter, giving a working area of 38 yards; this bed is 3′ 9″ deep, and contains the following layers of broken bricks and clinkers, viz., 1′ 9″ of 3″ to 1½″, 1′ 6″ of 1½″ to ¾″, and between rows of land drain pipes 6″ of clinker 3″ to 1½″. This bed is worked at the rate of 400 gallons per square yard throughout the 24 hours.

The Circular Polarite Fine Sprinkler Bacterial Oxidation Bed is 24 feet diameter, giving a working area of 50 square yards. This bed is 3′ 6″ deep, and contains the following layers of broken bricks and clinkers and polarite, viz., 9″ layer of a size ¾″ to ½″, 9″ of size ½″ to 3-16″, 1′ 6″ of a size ½″ to 3-16″, which includes the 3-inch layer of polarite 6 inches of a size 1″ to ½″ resting upon the brick channels. This bed works at the rate of 304 gallons per square yard throughout the 24 hours.

The reason the fine sprinkler bed works at this rate, *i.e.*, 304 gallons per square yard per 24 hours is due to the first or coarse sprinkler bed having a less working area than the second bed, the borough engineer having limited the speed of the first or coarse bed to 400 gallons per square yard; these speeds could be considerably increased, and still give a result well within the Conservancy standard.

The filtration through a Polarite Sprinkler Oxidising Bacterial Bed may safely be taken at 500 gallons per square yard per 24 hours, or 2½ million gallons per acre.

BACTERIAL SEWAGE PURIFICATION AT THE REIGATE CORPORATION SEWAGE WORKS.

THE PRIMARY BED WORKED AS AN ANAEROBIC BED, 4 FEET 9 INCHES DEEP. THE SECONDARY POLARITE OXIDATION BED, 3 FEET 6 INCHES DEEP, FED WITH CANDY'S AUTOMATIC REVOLVING SPRINKLER.

Average Rate of Filtration 550 Gallons per Square Yard per 24 Hours.

AVERAGE MONTHLY ANALYSES.

1899.	AVERAGE CRUDE SEWAGE.			EFFLUENT FROM ANAEROBIC BACTERIA BED.			EFFLUENT FROM POLARITE SPRINKLER BED.		
	Parts per 100,000.		Grains per Gallon.	Parts per 100,000.		Grains per Gallon.	Parts per 100,000.		Grains per Gallon.
	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.
March - - -	7·5	1·20	3·3	5·3	0·60	1·2	2·1	0·24	0·4
April - - -	6·95	1·18	3·0	5·1	0·53	1·6	2·0	0·20	0·36
May - - -	7·02	1·08	3·2	5·08	0 50	1·6	2·14	0·17	0·29
June - - -	8·20	1·30	4·0	5·60	0·63	1·90	1·90	0·19	0·39
July - - -	7·40	1·24	3·78	5·10	0·58	2·00	1·93	0·179	0·35
August - - -	6·98	1·19	3·20	4·75	0·525	1·16	1·80	0·175	0·347

The installation was started at the end of December 1898, but no regular analyses were made until March 1899.

In the Month of September 1899 the Primary Bed was converted into and worked as a Dibdin Coarse Contact Bed, 4 feet 9 inches deep, working at the rate of about 95 gallons per square yard per 24 hours, and the Polarite Oxidation Sprinkler Bed, 3 feet 6 inches deep, worked at an average of about 600 gallons per square yard per 24 hours, when the Dibdin Bed was drawn off.

AVERAGE MONTHLY ANALYSES.

1899.	AVERAGE CRUDE SEWAGE.			EFFLUENT FROM DIBDIN CONTACT BED.			EFFLUENT FROM POLARITE SPRINKLER BED.		
	Parts per 100,000.		Grains per Gallon.	Parts per 100,000.		Grains per Gallon.	Parts per 100,000.		Grains per Gallon.
	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.
September - -	During this month no regular results were recorded.								
October - - -	7·42	1·36	3·15	5·39	0·51	1·50	1·00	0·19	0·39
November - -	6·50	1·19	3·28	5·35	0·61	1·80	0·94	0·20	0·28
December - -	In the month of December the Dibdin Coarse Contact Bed was converted into an Aerobic Sprinkler Bed and no regular results were recorded.								

BACTERIAL POLARITE OXIDATION SYSTEM AT THE REIGATE CORPORATION SEWAGE WORKS.

BOTH THE COARSE AEROBIC BED (3 FEET 9 INCHES DEEP) AND THE POLARITE OXIDATION BED (3 FEET 6 INCHES DEEP) WORKED WITH CANDY'S AUTOMATIC REVOLVING SPRINKLER.

Filtration at the Average Rate of 400 Gallons per Square Yard per 24 Hours.

AVERAGE MONTHLY ANALYSES.

1900.	AVERAGE CRUDE SEWAGE.			EFFLUENT FROM FIRST SPINKLER BED.			EFFLUENT FROM POLARITE SPRINKLER BED.		
	Parts per 100,000.		Grains per gallon.	Parts per 100,000.		Grains per gallon.	Parts per 100,000.		Grains per gallon.
	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.	Free Ammonia.	Albuminoid Ammonia.	Oxygen absorbed in 15 minutes.
January	6·60	0·99	2·30	2·80	0·28	0·440	0·280	0·100	0·320
February	6·86	1·10	2·50	2·70	0·24	0·420	0·265	0·090	0·300
March	6·32	1·20	3·00	2·43	0·31	0·490	0·270	0·092	0·290
April	6·20	1·16	3·75	2·20	0·24	0·400	0·190	0·070	0·238
May	5·80	1·00	3·63	1·93	0·23	0·460	0·140	0·076	0·240
June	6·52	1·21	3·37	1·58	0·25	0·480	0·138	0·080	0·260
July	6·80	1·00	3·50	1·50	0·29	0·680	0·040	0·083	0·290
August	6·53	1·10	3·69	1·63	0·32	0·700	0·080	0·076	0·286
September	7·20	1·23	3·23	1·90	0·33	0·590	0·100	0·075	0·240
October	6·34	1·09	3·58	1·23	0·22	0·400	0·070	0·072	0·240
November	8·00	1·40	3·00	2·24	0·17	0·543	0·150	0·066	0·234
	Storm Sewage.			Storm Sewage.			Storm Sewage.		
	0·70	0·55	1·10	0·3750	0·15	0·210	0·016	0·046	0·120
Nov. 16th, heavy storm water sewage	—	—	—	* Filtering three times normal dry weather flow. 0·35	0·11	0·240	Filtering three times normal dry weather flow. 0·02	0·063	0·170

Sewage from Detritus Tank before passing on to first bed:—Free Ammonia, 7·0; Albuminoid Ammonia, 1·125; Parts per 100,000, Oxygen absorbed in 15 minutes, 2·4 grains per gallon.

The percentage of reduction in Albuminoid Ammonia is 93 per cent., and in Oxygen absorbed, 91 per cent.

Neither the effluents from the first Sprinkler Bed nor from the Polarite Sprinkler Bed have ever shown any signs of putrefaction after incubation.

A series of bacteriological investigations were made in November 1899, and again in 1900. In November 1899, with the first bed worked as a Dibdin Contact Bed, and the effluent finished by passing through the Polarite Oxidation Bed, the effluent was bacteriologically 92 times purer than the sewage. In November 1900, both beds having for 11 months been worked as Aerobic Beds with Condy's Automatic Sprinklers, it was found that the effluent from the Polarite Oxidation Sprinkler Bed was 2000 times purer than the crude sewage, the average number of bacteria in the crude sewage being 8,933,000, and in the effluent 44,300.

* These were the results obtained when the beds were working at three times the ordinary speed, *i.e.*, 12,000 gallons per square yard per 24 hours and dealing with three volumes in storm time, as required by the Local Government Board. The effluent from the Polarite Sprinkler Bed continued to be of a high degree of purity. It will be seen that under this system no increased area is required in order to deal with storm water up to three volumes.

TWENTY-EIGHTH DAY.

Tuesday, 5th March, 1901.

PRESENT:

The Right Hon. The EARL OF IDDESLEIGH (*Chairman*) *presiding.*

Mr. W. H. POWER, F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY, R.E.
Professor WILLIAM RAMSAY, F.R.S.
Colonel HARDING.
Mr. T. W. KILLICK.
Dr. J. BURN RUSSELL.

Mr. F. J. WILLIS, *Secretary.*

PRESENT ALSO:

Dr. G. McGOWAN.
Professor BOYCE.
Mr. COLIN G. FRYE.

Colonel HARDING; Examined.

Col. Harding. 5 Mar. 1901.

7034. (*Chairman.*) Colonel Harding, you are, I understand, an alderman of Leeds and the chairman of the Sewerage Committee of that city?—I am.

7035. And in that capacity you have had the charge of the Sewage Disposal Works of Knostrop?—I have.

7036. What is the population of Leeds?—About 430,000.

7037. Have you the combined or separate system of sewerage?—The combined, that is the street and roof waters go to the sewers and storm overflows are provided which carry direct to the river what the main outfall sewer cannot take.

7038. What is the volume of your dry weather flow of sewage?—About 16 million gallons.

7039. What system of sewage disposal have you at Knostrop?—After trying various systems of precipitation, among them that known as the A,B,C, the Corporation of Leeds in 1874 adopted lime precipitation, and this has been used ever since without material alteration of the works then provided, except that in 1898 additional tanks were made to increase the area of settlement.

7040. By that system you probably produce a large amount of sludge?—Yes. About 300 tons a day. When the additional tanks were brought into use the quantity rose to 400 tons, and it was found impracticable on the present site to deal with so large a quantity. Part of the tanks have, therefore, been used for experimental purposes.

7041. Have you found this sludge to have any market value?—At first, a small price was obtained for it, but that did not last long. For years past we have been very glad to let the farmers have it for nothing. They, however, fetch it very irregularly, and only if the carts are loaded for them. A suggestion has recently been made to use it in conjunction with coal dust and oil for the manufacture of briquettes for fuel. Experiments are being made. Practically sewage sludge is valueless, and very costly to handle by drying or pressing.

7042. Now, what purification do you obtain by your system of chemical precipitation?—About 50 per cent.

7043. This is mainly by the settlement of suspended solids?—Yes. If the Leeds sewage is filtered through filter paper, and the suspended solids wholly withdrawn, there is a purification by such withdrawal of 50 per cent. With the settlement area which it is possible to use at Leeds only about 60 per cent. of the suspended solids are removed, therefore the purification of 50 per cent. obtained by our lime precipitation is in part due to the action of the lime on dissolved impurities. It may be useful to add that a considerable amount of ferrous sulphate comes down as a trade effluent in Leeds sewage, and probably assists the process of settlement.

7044. Do you consider a system of chemical precipitation to be by itself sufficient for the purification of sewage?—No. It must be considered only as a first process to be followed by natural or artificial filtration.

7045. We know that you have for several years carried on a series of experiments in sewage treatment at Knostrop. What led the Corporation of Leeds to initiate these?—The pressure of the West Riding Rivers Board, of which I myself was a member. In November, 1897, the Corporation asked me to take the direction of the Knostrop works and to investigate the new suggestions about biological treatment of sewage. The site at Knostrop is only 25 acres. The neighbouring landowner objected very strongly to the presence there of these works, and to allowing the purchase of land for their extension. It was felt that to deal by broad irrigation with the rapidly growing volume of Leeds sewage would require probably 4,000 acres, while to adopt land filtration after precipitation might still require from 500 to 1,500 acres of land, according to its quality. At that time no suitable site of anything like these areas was available, even at a dozen miles from Leeds, and no doubt the idea in 1897 was that probably the experiments in artificial filtration would lead to some method of treatment which would very greatly reduce the required area, and so make the solution of the difficulty easier. The Corporation was led to experiment in the biological treatment of sewage by three objects:—

(1.) To find an effective means of purifying sewage on a relatively small area.

(2.) To obtain a higher degree of purification than had been possible by chemical precipitation alone.

(3.) To reduce the volume of sludge produced, or if possible to avoid its production.

7046. We come now to the experiments themselves. Your first experiments were, I understand, with Dibdin or contact beds?—Yes. Mr. Dibdin first experimented for us on a small bed of his own in London, and reported that Leeds sewage could be effectively treated on a bacteria bed, although ours is a mixture of domestic sewage and a large volume of various trade effluents. Samples of specific trade effluents were also sent to him, viz., iron liquor and tanyard liquor. In reference to these he found that in dealing with the iron liquor by itself, there was at first considerable oxidation of the iron salts, but this result was obtained at the expense of the efficiency of the beds, which soon became unfit for further work. The iron liquor exerted a strong antiseptic or sterilising action. When the liquor, however, was diluted with domestic sewage, the bacterial action, though to some extent checked, was not stopped, but nitrification did not proceed with its usual ease, oxygen being absorbed by the iron salts, and to that extent not available for oxidising the organic matter. In the case of tan liquors alone, undiluted by sewage, it was found that the effect of this double treatment, first on a coarse and then on a fine bed, gave nearly 80 per cent. purification, and removed the solids in suspension. Encouraged by Mr. Dibdin's report, and by what had been seen at Sutton and Barking, the committee determined to try a practical experiment at Knostrop with contact beds constructed under the advice of Mr. Dibdin.

7047. What was the extent of the experiments you made in this direction?—We began in the autumn of

1897 with a first pair of contact beds, which we call Nos. 1 and 2, one a rough and the other a fine bed, each of which had an area of one-eighth of an acre. Later we constructed two more pairs of beds, Nos. 3 and 4, and Nos. 5 and 6, all of similar area, and we had further two more beds, again of one-eighth acre each, which were used as single beds, No. 7 for experiments in single contact filtration of the effluent from our lime precipitation process, and No. 8 for single contact filtration of septic tank effluent. Our experiments, therefore, were with eight beds, covering in all an area of one acre. The experiments with Nos. 1 and 2 have lasted nearly 3½ years, those with Nos. 3 and 4, which were started in November, 1898, 2½ years; those with Nos. 5 and 6, and also 7 and 8, all started in the spring of 1899, have extended over two years. The various experiments have been fully detailed in a report published in July, 1900, which has been communicated to the Commission.

7048. What material did you use for the beds?—The first pair, Nos. 1 and 2, were filled with gas coke, which for the coarse bed was larger than 3in. and for the fine bed was from 1½in. to ¼in. The floor was drained by rows of agricultural drain pipes, 2ft. apart, leading to the outlet valves through a brick connecting drain. The other two pairs of beds, Nos. 3 and 4, and Nos. 5 and 6, were filled with clinker from our destructors. This material was thought to be very cheap, as it could be had for nothing; but as it is produced, the material takes the form of slabs, and considerable cost is incurred in breaking it up, and in sorting it, so that there is little if any advantage over coke in regard to cost. The fine beds of these two pairs, viz., Nos. 4 and 6, were both filled with clinker ¼in. to in., but No. 3 coarse bed was fileld with clinker 1in. to ½in., while No. 5 was larger size, viz., 2in. to 1in.

7049. Were you able to judge from the results as to the relative value of coke and clinker as materials for beds?—Well, we found that our clinker beds never reached the analytical results of the first pair of coke beds. I do not think, however, that this was so much due to the material as to other circumstances. The coarse coke bed was 5ft. deep, and the fine bed 6ft. deep, while the clinker beds were only 3ft. deep. The coke beds had also been better under drained than the clinker beds. I have seen good results from various materials, and I don't see why equally good results should not be obtained from clinker or from coke, if the materials are used under equal conditions as to depth of beds and size of the material.

7050. How did you find the depth of your beds affect their working?—We constructed our second and third pair of beds with a depth of only 3ft., in the belief that we should secure better aeration, and that we should be able to give more frequent fillings. We hoped that with shallower, and, therefore, cheaper beds we could by more frequent fillings deal with as great a volume as on the deeper and more expensive beds, but we were disappointed. The results were never so good as with the deeper beds, and we could not give more fillings. Our experience was in favour of the deeper beds, and this is of special value where the available area is limited.

7051. Did you fill the beds slowly or quickly?—After various experiments we settled to filling in one hour or less. It seems desirable to fill as rapidly as practicable, and the speed need only be limited by the question of distribution. If you fill slowly the lower portion has had sufficient contact before the top of the bed is reached, and if also you empty slowly, then the lower portion of the beds is water-logged much longer than the upper, and it is impossible for it to be effectively aerated.

7052. What system of distribution did you adopt?—In our first pair of beds we began by an elaborate system of troughs, filled with holes, but we found the troughs constantly silting up with sludge, and the holes very soon stopped up. In the later beds we fed the sewage on to one end of the beds in a thin stream over a lip the full width of the bed. After a few days the coke under the lip was choked on the surface, and then the flow spread over it further, until after some weeks or months it passed almost to the far end of the bed before it could get down. When the bed became pooled or flooded we were oblige to fork the surface, or even to remove the upper surface. On the whole we found it the most convenient plan to provide channels in the material itself, and from time to time to turn them over and so vary their position.

7053. Did you try the value of different periods of contact?—Yes. Mr. Dibdin told us when we started work in 1897 that he had found two hours the best term for the beds to stand full. We tried shorter periods with inferior results, and found no appreciable advantage in increasing the period to four hours. It would seem that the supply of oxygen is absorbed in the two hours' contact, and if so no benefit can be gained by keeping the sewage longer in the bed. The condition would tend to change from aerobic to anaerobic. Our experience, therefore, confirms Mr. Dibdin's.

7054. You told us that you found it well to fill the beds as fast as consistent with effective distribution. What about the emptying?—We found that one hour for filling and one for emptying were convenient periods. No material inconvenience arises from emptying fast, while slow emptying reduces the period of aeration, and especially so for the bottom of the bed. It should be added that when the main flow has ceased the bed continues to trickle for hours and days. The spongy matter which forms on the surfaces of the material gives up its water slowly, and it is during the time of trickling that the very best samples are obtained. At first, especially with rapid emptying, the flow is turbid and unsatisfactory, owing no doubt to insufficient aeration in the lower parts of the bed and in the channels and pipes, and also to accumulation of solid matter in these. On this account in taking samples our plan was to take a sample of the first rush, and others every 10 minutes to the end of the hour. It was the average so obtained which was then analysed.

7055. Tell us now as to the period of rest required for aeration between the fillings?—Under normal conditions we found three fillings per 24 hours convenient, viz., cycles of eight hours. The time table was one hour to fill, two hours' contact, one hour to empty, and four hours rest. With two fillings a day you have eight hours' rest, and with one filling 20 hours' rest. No doubt with the longer periods of rest there is more complete draining and therefore more effective aeration of the beds, and better results, but of course with fewer fillings the volume dealt with per acre is very small and may make the process prohibitively costly. Apart from the question of cost and the large area of beds that would be required it might be well to give only one filling per 24 hours during normal flow, and in time of rain increase to three or even six fillings for short periods, and so deal with six volumes or five dilutions.

7056. What was the period of incubation for the beds?—It was found that new beds required about six weeks to get into condition, the early effluents being unsatisfactory and putrescent; but at the end of this period a rapid and permanent improvement in the filtrate took place.

7057. What was the condition of the sewage as put on the beds?—We tried a great variety of experiments in double contact filtration, the details of which will be found in the report of July, 1900. It may suffice here to say that we experimented—

1. With sewage absolutely crude, except for what was kept back by the one-inch grating at the entrance of the works;
2. With sewage from which the grit or road detritus had been settled;
3. With sewage which had been passed through screens of ¼in. mesh, so as to keep back small pieces of paper, matches, tea leaves, etc., which with fibre were found to form a mat on the surface of the coke;
4. With sewage passed through a fine screen of 20 per inch to keep back the fine fibre which comes into Leeds sewers from woollen mills;
5. With sewage settled to various degrees.

In all these experiments the sewage contained all the dissolved impurities, but the suspended solids were more or less reduced. It may interest the Commission to know that while of course the suspended solids vary largely from hour to hour, yet an average taken upon the analyses of many months in 1899 gave 44 grains per gallon of suspended solids in Leeds sewage. I see that in one period of experiment, from August to November, 1899, the average of suspended solids was as high as 57 grains per gallon. The withdrawal of the grosser solids and fibre by screening only removes matters which do not usually come into the analysis. In these experiments I find that the averages of suspended solids, even with partially settled and screened sewage, rarely fell below 32 grains per gallon. As a rule. the rough beds were found to keep back from 65 to 75 per cent. of the solids

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in suspension. The solids in suspension in the final filtrate amounted to:—

3·51 grains per gallon when dealing with crude sewage,
2·19 ,, ,, ,, ,, ,, ,, screened sewage,
1·3 ,, ,, ,, ,, ,, ,, partially settled sewage,

and these differences account for the turbidity noticed in connection with the first flow while dealing with crude or screened sewage, and for the improved appearance of the effluent in dealing with partially settled sewage; and there can be no doubt that with thoroughly settled sewage admirable results would be obtained by double filtration. With septic tank effluent there would be generally only 8 or 10 grains of suspended solids to be dealt with, so that in all the experiments I am alluding to, viz., sewage screened or partially settled, the difficulties were much greater than those which arise in dealing with septic effluent. These difficulties in dealing with crude sewage arise from the suspended solids and are (1) the formation of sludge on the surface of the coke, (2) the reduction of capacity of the beds.

7058. What kind of results did you obtain as regards purification by your double contact filtration?—From experience gained during over three years in treating Leeds sewage on contact beds, it was found that whether dealing with crude sewage, screened sewage, or partially settled sewage, variable but very good effluents could be obtained, much superior to those from lime precipitation. Their chemical analyses gave results which were generally within the limit of one grain per gallon oxygen absorbed and ·1 of albuminoid ammonia; limits which have in recent years been accepted by the Lancashire and Yorkshire Rivers Boards as a provisional standard of purity for effluents going into a stream not used for drinking purposes. The following are the average analytical results obtained over long periods, as detailed in the report referred to:—

TABLE showing the Average Analyses of the Crude Sewage and the various Filtrates from Nos. 1, 2, 3, 4, 5, and Contact Beds.

Grains per Gallon.	Date.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.
Crude sewage	Oct. 27th, 1898, to Oct. 9th, 1899.	117·0	40·7	1·72	·809	8·04	—
Filtrate from Bed No. 1		75·3	11·5	1·098	·318	2·48	—
,, ,, No. 2		68·4	1·9	·31	·081	·50	·392
Percentage purification effected by Bed No. 1		—	71 per cent.	36 per cent.	60 per cent.	69 per cent.	—
Percentage purification effected by Beds Nos. 1 and 2		—	95 per cent.	81 per cent.	90 per cent.	93 per cent.	—
Crude sewage	Nov. 1898 to June 1900.	118·4	42·8	2·02	·964	8·80	—
Filtrate from Bed No. 3		82·3	12·6	0·920	·289	2·07	—
,, ,, No. 4		73·0	3·3	0·581	·108	·655	·261
Percentage purification, Bed No. 3		—	70 per cent.	54 per cent.	70 per cent.	76 per cent.	—
Percentage purification, Beds Nos. 3 and 4		—	92 per cent.	71 per cent.	88 per cent.	92 per cent.	—
Crude sewage	Mar. 1899 to Nov. 1899.	124·8	46·1	2·05	·997	9·12	—
Filtrate from Bed No. 5		81·9	13·7	1·23	·397	2·91	—
,, ,, No. 6		71·5	3·3	·666	·141	·790	·127
Percentage purification, Bed No. 5		—	70 per cent.	39 per cent.	60 per cent.	68 per cent.	—
Percentage purification, Beds Nos. 5 and 6		—	92 per cent.	67 per cent.	85 per cent.	91 per cent.	—

These results were obtained notwithstanding the large volume and variety of trade effluents mixed with Leeds sewage. The chief difficulty occurred in connection with large quantities of iron liquor (ferrous sulphates and chlorides) coming down in this sewage, and representing as much as five tons of metallic iron per 24 hours. Generally a large part of this iron was retained by the beds, but at times, especially in summer, some of it came through in solution and afterwards settled out as a buff-coloured flocculent hydrated ferric oxide.

The final effluent evidently contained dissolved oxygen, for it was found to support fish life; coarse fish, such as carp and gold fish, living in it for long periods, some of them for over three years; while there was much green growth in the basin and channels. Mention may be made of Vaucheria, an alga which is said to grow in swift flowing and therefore well aerated streams. The usual pond life was also represented in great variety in the basin, including larvæ of Chironimus, Nais, Cyclops, small worms, etc. In the body of the filter were earthworms and great quantities of Podura aquatica. These evidences of aeration are a special and valuable feature of biological effluents which, unlike the effluents from chemical precipitation, are rarely liable to subsequent putrefaction, but on the contrary contain elements of further purification, and will probably improve on passing to the streams.

7059. You have told us your samples for analyses were taken from an average of the total flow. By whom were the analyses made?—At first by Mr. Dibdin, but since October, 1898, by the resident chemist at our works, Mr. W. H. Harrison, M.Sc.

7060. To what extent did you find nitrification?—In these experiments analyses never showed any important percentage of nitrates, which, indeed, only began to appear after two months' work, and never exceeded ·5 per gallon, the average being considerably less. This was probably due to the composition of Leeds sewage, which includes readily oxidisable trade effluents.

7061. What was the effect of frost on the working of your contact beds?—As bacterial action is only possible within a limited range of temperature, careful records were kept to determine if in cold weather the temperature of the beds was liable to fall below that limit. An examination of these records shows that the temperature of the beds is determined by the sewage, and only in a very minor degree by the atmosphere. This is illustrated in the following table:—

TABLE showing effect of Frost upon the Beds.
(Temp. = °F.)

DATE. Fortnight ending	State of Weather.	Rough Bed (No. 3). Temp. of Sewage.	Temp. of Atmosphere.	Temp. of Bed before filling.	Temp. of Bed when full.	Temp. of Filtrate.	Temp. of Bed when empty.	Fine Bed (No. 4). Temp. of Atmosphere.	Temp. of Bed before filling.	Temp. of Bed when full.	Temp. of Filtrate.	Temp. of Bed when empty.	Percentage Purification as calculated on Alb. NH_3 Test.	Percentage Purification as calculation on Oxygen absorbed Test.
Dec. 8th, 1899 - -	No Frost	58·9	45·5	56·3	57·2	56·7	55·9	45·5	54·8	54·8	54·6	54·5	90 %	93 %
Dec. 8th to Dec. 29th	Frost -	53·1	31·2	49·4	49·8	49·4	49·2	31·9	47·4	46·1	46·1	46·0	91 %	92 %

AVERAGE TEMPERATURE of Sewage, Atmosphere, and Rough and Fine Dibdin Beds during a Period of Six Months.
(Temperatures are in degrees F.)

Average Temperature from	Temperature of Sewage sent on to Rough Bed.	Rough Bed (No 1). Temp. of Atmosphere at time of filling.	Temp. of Bed immediately before filling.	Temp. of Bed when full.	Temp. of Filtrate.	Temp. of Bed when empty.	Rough Bed (No. 2). Temp. of Atmosphere at time of filling.	Temp. of Bed immediately before filling.	Temp. of Bed when full.	Temp. of Filtrate.	Temp. of Bed when empty.
December 17th to December 30th, 1898 - -	54·7	38·8	56·1	55·5	55·3	55·2	41·3	54·8	54·8	55·1	55·0
December 31st to January 13th, 1899 - -	52·0	39·2	51·9	51·7	51·9	51·5	39·4	50·9	51·1	51·2	50·9
January 14th to January 27th, 1899 - -	51·9	36·7	51·9	51·2	51·4	51·3	37·7	50·7	50·9	51·0	50 9
January 28th to February 10th, 1899 - -	52·9	39·5	53·0	51·9	52·3	52·4	39·4	51·4	51·8	51·5	51·3
February 10th to February 24th, 1899 - -	54·6	39·7	54·0	53·6	53·8	53·5	40·2	52·5	52·8	52·6	52·5
February 25th to March 14th, 1899 - -	58·9	41·3	57·1	57·2	57·5	57·2	41·6	54·3	54·5	54·8	54·3
March 15th to March 25th, 1899 - - -	56·5	45·7	56·4	56·7	56·9	56·5	34·8	54·8	57·3	57·1	56·1
March 26th to April 8th, 1899 - - -	55·1	47·3	55·3	55·0	55·2	55·1	47·6	55·1	55·1	55·2	54·8
April 10th to April 21st, 1889 - - - -	55·3	42·4	54·4	54·8	54·9	54·6	42·2	53·7	53·4	53·9	53·9
April 22nd to May 6th, 1899 - - - -	58·5	52·7	57·3	57·8	58·2	57·7	47·9	56·1	57·3	57·3	56·8
Average - - - -	55·0	41·2	54·7	54·5	54·7	54·5	41·2	53·4	53·8	53·9	53·6

It will be seen that in the seven hours occupied in passing through both beds the loss of temperature from the sewage to the final effluent was only 1½ degrees. During periods of rest the heat in the beds rose to 70 and 80 degrees. During the past few years the winters have not been severe, and it was only during the winter 1899-1900 that any valuable data bearing upon this subject could be collected. They show that during fairly cold winters the purification effected by this process of contact filtration is not appreciably checked.

7062. Did any nuisance arise in connection with contact bed filtration?—None whatever. Even on digging deep into the beds which had been receiving Leeds sewage for long periods, there was no smell but that peculiar to garden soil.

7063. We come now to the important question of maintenance of capacity of the beds. In your opinion can contact beds be used indefinitely?—No. Our experience was that in dealing with crude sewage, and even with screened and partially settled sewage, there was a steady loss of capacity. The process was found to give good results as to effluents, but the real difficulty is that a working capacity of the beds cannot be maintained, except at an impracticably low scale of work. It must be noted that the difficulty arose almost exclusively in the first or rough beds. The fine beds gave us no trouble. This would be due no doubt partly to the fact that the fine beds received 75 per cent. less suspended solids than the rough beds, but also that as the capacity of the rough beds declined, the volume passing on to the fine beds became continually less, so that the upper part of these beds was never waterlogged, and was always aerated, and the fine beds never, except in the first weeks, got their full dose of work. It was suggested to us that if accumulation arose in the beds, it could be consumed by rest, and the beds thus restored to their original capacity. We found, indeed, that by rest some of the accumulations were reduced, but the greater part of the capacity recovered was soon lost again. The increase of capacity on restarting is due in large part to the more complete draining of the bed during rest, and to drying up of spongy matter in the body of the bed. From the experience at Leeds, the conclusion was inevitable that there is steady reduction of capacity in contact beds, and more especially in rough beds, and that the capacity can only to a small extent be recovered. Experiments were made to wash out the beds, but were not successful, and it would seem that when a bed is choked it can only be restored by a sorting and screening of the material, a process which I fear is prohibitively costly. In this coarse bed, the choking, though greatest on the surface, went through the bed. I put in a table showing the variations of capacity of the Leeds beds over long periods.

TABLE SHOWING THE VARIATIONS IN CAPACITY OF CONTACT BEDS.

No. 1, ROUGH CONTACT BED.

Capacity before putting in Coke = 174,800 Galls.
Original Water Capacity after putting in the Coke = 83,300

	Galls.	
1897 :		
1 Oct.	83,300	Crude Sewage (3 fillings).
1 Nov.	74,000	42 grains per gallon of suspended solids.
1 Dec.	64,000	"
1898 :		
1 Jan.	57,100	"
1 Feb.	45,400	"
	Bed rested 14 days.	
18 Feb.	55,900	Lime Effluent.
1 Mar.	53,000	Screened Sewage (3 fillings).
1 Apr.	45,000	39 grains per gallon suspended solids.
27 Apr.	40,000	"
	Bed rested 7 days.	
5 May	45,800	(2 fillings).
16 June	43,200	"
	Bed rested 33 days.	
28 July	56,500	"
1 Sept.	42,000	"
	Bed dug over.	
1 Oct.	46,500	Half-settled Sewage (2 fillings).
1 Nov.	44,000	Say 20 grains per gallon suspended solids.
	Bed rested 14 days.	
1 Dec.	45,000	(3 fillings).
1899		
1 Jan.	36,000	"
1 Feb.	31,800	"
1 Mar.	29,000	Resting on Sundays.
1 Apr.	25,000	Crude Sewage do. (3 fillings)
6 May	22,700	Resting Wednesdays and Sundays.
3 June	23,400	Resting alternate days (*i.e.*, 1½ fillings per day).
1 July	25,600	"
1 Aug.	26,800	(1 filling every day).
9 Sept.	27,300	"
7 Oct.	26,900	"

N.B.—The increase of Capacity from 1st July 1899, is more apparent than real, as with only 1 filling per day the Bed would have a longer time to drain.

No. 3, ROUGH CONTACT BED.

Capacity before putting in Coke = 102,094 Galls.
Original Water Capacity after putting in the Coke = 51,800

	Galls.	
1898 :		
21 Nov.	51,800	Partially settled Sewage (3 fillings).
5 Dec.	46,600	Rested on Sundays. 35 grains per gallon suspended solids.
1899 :		
2 Jan.	38,100	"
1 Feb.	34,500	"
13 Feb.	30,400	Grit settled Sewage (3 fillings),
1 Mar.	28,500	Rest on Sundays. 39 grains per gallon suspended solids.
27 Mar.	23,600	"
	Rested 18 days.	
18 Apr.	28,600	"
2 May	21,700	"
	Surface removed.	
31 May	24,900	Beds rest alternate weeks.
28 June	22,500	"
		Resting alternate days. (3 fillings).
1 Aug.	25,000	"
1 Sept.	25,000	"
1 Oct.	24,500	"
1 Nov.	21,200	"
1 Dec.	21,700	"
1900 :		
1 Jan.	18,000	"
10 Mar.	14,700	"
	Rested 16 days and Surface cleaned.	
26 Mar.	21,200	"
1 Apr.	21,000	"
1 May	18,500	"
1 June	18,000	"
1 July	18,200	"
12 Oct.	12,900	"

No. 5, ROUGH CONTACT BED.

Capacity before putting in Coke = 102,094 Galls.
Original Water Capacity after putting in the Coke = 53,100

	Galls.	
1899 :		
28 Feb.	53,100	Grit settled Sewage. Rest on Sundays.
14 Mar.	46,600	39 grains per gallon suspended solids.
1 Apr.	42,000	"
9 May	32,500	(2 fillings per day). 4 hours contact.
1 June	30,500	"
5 July	22,400	(2 fillings per day). 2 hours contact.
2 Aug.	29,400	"
16 Aug.	29,900	(2 fillings per day). 4 hours contact.
13 Sept.	28,300	"
	Rested 25 days.	
24 Oct.	30,800	"
22 Nov.	25,400	"
1900 :		
9 Mar.	27,600	(3 fillings per day). 2 hours contact.
6 April	23,000	"
4 May	18,100	"
1 June	13,200	"
	Rested 20 days and Surface cleaned.	
22 June	20,500	"
20 July	16,600	"
17 Aug.	12,700	
13 Sept.	9,300	
	Bed cleaned.	
25 Oct.	21,000	
22 Nov.	14,900	
20 Dec.	11,700	

No. 7, SINGLE CONTACT BED.

Capacity before putting in Coke = 55,700 Galls.
Original Water Capacity after putting in the Coke = 55,700

	Galls.	
1899.		
24 Mar.	55,700	Lime Effluent containing 10 grains per gallon suspended solids.
21 Apr.	50,308	"
5 May	48,600	"
2 June	43,600	"
1 July	32,000	"
1 Aug.	33,000	"
1 Sept.	28,500	"
20 Oct.	21,600	"
	Bed rested and turned over.	
1900.		
3 Jan.	53,500	"
2 Feb.	50,300	"
1 Mar.	46,000	"
1 Apr.	41,000	"
1 May	36,500	"
1 June	31,000	"
5 July	25,600	"
28 Sept.	20,700	
21 Dec.	17,500	

N.B.—Loss of Capacity in Nos. 7 and 8 Beds was largely due to the consolidation of the material.

No. 8, SINGLE CONTACT BED.

Capacity before putting in Coke = 29,500 Galls.
Original Water Capacity after putting in the Coke = 29,500

	Galls.	
1899 :		
23 May	29,500	Septic Tank Effluent average 13 grains per gallon of suspended solids.
6 Apr.	29,800	"
4 May	27,100	"
2 June	23,000	"
1 July	18,500	"
1 Aug.	16,000	"
21 Sept.	10,700	"
	Bed rested and turned over.	
10 Nov.	26,900	"
1 Dec.	24,500	
1900 :		
1 Jan.	19,500	
1 Feb.	17,000	
1 Mar.	16,000	
1 Apr.	13,500	
4 May	12,200	
1 June	9,800	
1 July	11,000	
24 Aug.	9,700	
19 Oct.	9,500	
14 Dec.	10,500	

The loss of capacity would seem to be due to the following causes, some of which are remediable, and others not:—

(1) The passing of sand, coal dust, and road detritus into the bed.—These matters must be kept out, for bacterial action cannot reduce them.

(2) The degradation of the material of the filter.—It is found that coke, though at first carefully sorted to larger size, soon becomes broken down. No doubt this arises to a less extent with clinker, which, however, is apt to take the form of slabs, and is not very suitable for a coarse bed. Burnt ballast is very liable to reduction.

(3) The consolidation of the material of the bed.—In connection with the single contact beds, Nos. 7 and 8, the loss of capacity in those cases was largely due to this cause. The material of a bed must be of very even size, or gradually the smaller pieces, by the slight movement due to filling and emptying, tend to fit themselves in between the larger, so as to approximate to a solid mass. As we have seen, even equal sized material in course of time becomes broken down into unequal, and so consolidation takes place.

(4) More organic solids coming on to the bed than the bed can digest.—Fibre and certain vegetable matters are very slowly dissolved and tend to accumulate in the beds unless the rate of working is very slow. The screening-off of some of these matters can be accomplished within reasonable cost.

(5) The presence in the sewage of matters which cannot be reduced by bacterial action, other than the sand and road detritus.—Whether such matters exist in the sewage in an originally irreducible form, or whether such irreducible form is reached as a result of change in the bed, it is difficult to determine. But it is certain that a coarse bed which has been long at work is found to contain a large quantity of matter akin to humus or garden soil, and which cannot be further reduced.

(6) The retention in the bed of mineral solids originally in solution, but which, by the oxidising action of the beds, come into suspension; as, for instance, the iron liquors containing ferrous sulphates and chlorides, a large part of which are found to be retained in the beds, the pieces of coke being often heavily coated with red iron deposit.

7064. You speak of the screening and washing of the material of the bed being prohibitively costly? Have you any figures?—The cost of sorting and screening out our No. 1 bed, which had an area of ⅛th acre, was nearly £80, or at the rate of £640 an acre. It is perhaps scarcely fair to take this experimental work without suitable appliances as a basis of estimate, but in any case such screening out of broken down material and accumulations—say once a year—must necessarily be costly. If our No. 1 bed had been dealing with septic effluent instead of crude sewage the necessity for cleaning it would not have arisen so soon, and in that case too, finer material could be used, which would be cheaper to handle, because it can be spaded. No doubt this is why Mr. Fowler found at Manchester that the material of their free beds could be washed for 1s. 6d. a square yard, or £360 an acre. Of course, it must be borne in mind that in land treatment the surface must be broken up by ploughing, and that this too costs money.

7064*. How long did you work your No. 1 rough bed before it became choked?—From October, 1897, to October, 1899—two years. The original sewage capacity had been 83,300 gallons. In March, 1899, it had fallen to 27,000 gallons. From that time the work of the bed was reduced, giving one day's rest in seven, then two days' rest in seven, and finally alternate days of rest and work. During the summer of 1899 it was found possible to maintain capacity by resting alternate days, or by working every day with one filling only. The capacity, which had fallen in May to 22,000 gallons, with one filling only per day, recovered apparently to 27,000 gallons, but this was no doubt due to the more complete draining during the daily rest. The experience with rough beds, Nos. 3 and 5, was similar.

7065. Did you make any analyses or examination of the accumulations?—Yes. On March 21st, 1899, in order to learn what was the nature of the deposit which was accumulating in the beds, the rough bed was dug down to the bottom, and a spadeful of the coke was taken from the bottom, middle, and near the top and put into a bucket. The deposit on the coke near the top was of an earthy character, and lower down where it was wetter it took the form of at first a brown, and near the bottom a black odourless slime. On analysis the deposit was found to contain 85 per cent. moisture. Of the remaining 15 per cent. about 7½ was organic matter, some of which was fibrous, and the remaining 7½ was mineral, about half of it being ferric oxide. When the experiments with No. 1 bed were stopped in October, 1899, the material was taken out, and coke only replaced which could not pass through 1½ inch mesh. This was found to only half fill the bed, so that what passed through 1½ inch mesh and was rejected, represented half the contents of the bed. Therefore, if a material could have been used not liable to degradation, probably one-third of the loss of capacity would have been avoided. 20·39 per cent. by volume of the rejected matter was true deposit, but contained 70 per cent. water. It had been to some extent dried or drained by the resting of the bed, and no doubt in working conditions the deposit would contain nearly 90 per cent. of water. Every grain of matter retained by the bed holds up 9 grains of water, so that the accumulation consists largely of water retained by the spongy matter. The deposit itself, dried and exposed to red heat for five minutes lost 36½ per cent. by weight. Of the remainder about 30½ per cent. was ferric oxide, 16 per cent. sand, and the remaining 17 per cent. carbon, present as coke, due no doubt to degradation of the filtering material.

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7066. Notwithstanding these accumulations and consequent loss of capacity, you have no doubt that there was a large digestion by the rough bed of the suspended solids which passed into it?—Certainly. A large part was digested. It is difficult to get at any reliable estimate of the sludge digested by the beds. Taking No. 1 rough bed, the total volume dealt with, from October, 1897, to October, 1899, was 38 million gallons, and if the average of suspended solids kept back by the bed is taken at 33 grains, then 178,000lbs. of dry solids, or 1,780,000lbs. of sludge (90 per cent. water), has been left on that bed, or, at 10lbs. per gallon, 178,000 gallons. As the final accumulation in the bed was 56,000 gallons, it would seem that this bed had digested 68 per cent. The quantity is no doubt less, as the upper sludge left on the bed contains only 85 per cent. water. On the other hand, the reduction of capacity is partly due to breaking up of the material of the bed, and some matters at first in solution are thrown into suspension and retained. As a rough estimate, 60 to 70 per cent. may be taken as a fair approximation of the sludge digested by this bed.

7067. Briefly, what results did you obtain from your beds, Nos. 7 and 8, which I understand were used with lime settled effluent and with septic tank effluent?—We never got from these single contact beds results which reached the Rivers Board standards. We found the same thing in the filtrates from the single contact beds used with the Cameron closed septic tanks. In all these cases the results of single contact filtration were fair, but not good enough.

7068. Now as to the area of contact beds that would be required for Leeds sewage? Have you formed an opinion?—Well, when our double contact beds were in good working condition and dealing with about 50,000 gallons per filling, and three fillings a day—that is, 150,000 gallons per 24 hours—this would represent 1,200,000 gallons per day per acre, since the area of each bed was about ¼ acre. There were, however, two beds, a rough and a fine, so that only 600,000 gallons per acre of beds could be dealt with. Allowing for necessary periods of rest half a million gallons per acre might be reckoned; and for 16,000,000 gallons, the Leeds dry weather flow, 32 acres would be required. But the beds would not last long at this rate, and the volume dealt with would rapidly diminish. If as a basis of calculation the reduced rate of working of the summer of 1899, viz., one filling per day, is taken, there would be required 96 acres of double beds, an area which, I fear, would be prohibitively costly. Apart from cost, an area which would permit of one filling a day of the dry weather flow would be convenient, because the fillings could be increased during rain and for short periods to three or more per day. But I have come to the conclusion that

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for Leeds sewage the system of intermittent or contact filtration is impracticable, although good filtrates are certainly obtained.

7069. Should you continue to hold that opinion if the Leeds sewage were first thoroughly settled or passed through septic tanks?—No. All my replies to previous questions had reference to dealing on intermittent contact beds with either crude sewage or sewage containing the greater part of the finely-divided suspended solids. I think there can be no doubt that with Leeds sewage which had been so thoroughly settled as to contain only, say, 5 grains per gallon of suspended solids, the double contact beds, especially with the finer material which could then be used, would not only give admirable filtrates, but would have a much longer life, might last, in fact, for many years, though I fear that even so used there would be ultimate choking. With thoroughly settled sewage, however, there would be a great production of sludge, and one object of our experiment had been to find means of reducing the production of sludge. With regard to the double contact filtration of septic tank effluent, our experiments have lasted sufficiently long to show that excellent filtrates can be obtained, but I do not wish to give any strong opinion yet as to the choking up of the beds in dealing with septic tank effluent. So far as it goes our experiment shows that there is persistent reduction of capacity in the first bed; but it is fair to say that our trials were made with the effluents from septic tanks which had been long at work without emptying, and which in consequence were passing out over 15 grains per gallon of suspended solids. In a septic tank working with a 24-hour flow there should not be more than 8 grains per gallon of suspended solids, and if our experiment had been carried out in these conditions no doubt the reduction of capacity would have been much less. I should like to add that the six filter beds dealing with the effluent from the covered septic tanks, which for the whole period carried on an average of 12·3 suspended solids in grains per gallon, have after working for 18 months only shown an average loss of one-third capacity. At starting, in September, 1899, the sewage capacity of the six tanks was 31,060 gallons, and recent measuring in February showed that the total loss of capacity was 10,600 gallons, or about one-third. These beds, however, have only had little more than one filling a day over the whole period, but they show that with light working of septic effluent capacity can be fairly maintained. Inasmuch, however, as many analyses made at Leeds show that the finely divided black suspended solids in septic tank effluent are to the extent of over 50 per cent. mineral and not in condition to be further reduced by bacterial action; and as in double contact filtration of such effluent the filtrate is with fairly fine filter material generally brilliant and clear, the conclusion seems inevitable that if these indigestible matters don't come out they must tend to ultimately clog the filter. At Manchester it is suggested by Mr. Fowler that these matters become part of the filtering material. This may be so if they aggregate into lumps, but if they remain finely divided they will fill up the interstices of the bed material, bring about consolidation, and so gradually reduce capacity. Anyway, contact beds seem to me much more likely to succeed if they are used to purify thoroughly settled sewage or septic tank effluent, and it is an important advantage of the septic tank that it equalises the conditions of the sewage, whereas if more or less crude sewage is put on the beds the conditions are constantly varying, especially if there is any large admixture of trade effluents. In regard to trade effluents regulations should be adopted by all local authorities to ensure that large flushes of trade refuse shall not be sent into sewers, and this is easily provided against by the use of storage tanks at the manufactory. It should also be insisted upon that manufacturers should, at their works, settle suspended solids as much as possible. I should like to remind the Commission that contact bed experiments have now been tried in many places, and notably at Sheffield, where excellent filtrates have been obtained even from crude sewage, but rarely have careful observations been made to gauge reduction of capacity of the beds. The experience of the next twelve months will prove very useful in this respect. I should wish also to add that if a material can be found for contact beds of even size and not liable to reduction the life of the beds would be greatly lengthened, for loss of capacity is due, I believe, more to reduction and consolidation of the material of the bed than to the undigested matters brought down by the sewage. The movement of the material of contact beds due to alternate filling and emptying tends to reduction and consolidation. From this point of view broken granite of perfectly even size would seem an ideal material, but on account of its weight would be very costly in most places. The question of the material which can practically be used is necessarily dependent on local conditions.

7070. (*Mr. Power.*) I have made a note to ask you whether you had tested the aeration of the effluent after 4 hours' contact. Was it generally tested in these experiments—the aeration of the effluent?—The aeration of the effluent has only been tested recently sinc we have had the apparatus devised by Professor Ramsay, but previously the aeration was not specially tested. We drew our conclusions from the usual chemical analyses.

7071. Then you will have been testing the aeration of the Leeds filter of later date—the triple filter?—Yes, and we have, of course, recently made experiments as to the dissolved oxygen.

7072. With the Dibdin and the other effluents, the Dibdin and the Ducat?—Yes.

7073. We shall be able to compare them together?—Yes.

7074. The point arises again where you speak of fish (Question 7058): "The final effluent evidently contained dissolved oxygen, for it was found to support fish life." Perhaps you will be able to give some figures about that; you have tested the aeration of that effluent since?—Yes, the dissolved oxygen in double contact filtrates, whether from crude sewage or from septic tank effluent, did not exceed, I think, in any case more than 2 c.c. per litre, and in some cases the filtrate contained no dissolved oxygen. In the case of the Cameron filters the dissolved oxygen was always extremely small, and may be said to be almost nil; and under the best system of double filtration I do not think we had dissolved oxygen to a greater extent than 2 c.c. per litre.

7075. Speaking generally of the Ducat filtrate, what would the aeration of that effluent be?—Oh, it would be considerably more.

7076-7. Considerably more?—Considerably more. I should be glad to give you those figures at once.

No, I only want a general idea.

7078. (*Chairman.*) You did not, I suppose, try anything except coarse fish?—No, I did not.

7079. You do not know what salmon would do, or trout?—No, salmon are not available at Leeds.

7080. (*Mr. Power.*) Do you consider that with the double filtration, the aeration of the final effluent, such as there is, is mainly affected in the second bed—by the second contact?—I should think that any dissolved oxygen arising would be due to the passage through the second bed. That is evidenced by the experiments we made with the Cameron filters, where you had single filtration of septic effluents, and there as a rule we found scarcely any dissolved oxygen. It was where we had double filtration that we found dissolved oxygen in the filtrate.

7081. As to the suspended solids, is not this a question of the condition of the raw sewage? Do you think the matter in suspension varies largely in Leeds from time to time during different hours of the same day and from day to day?—Very largely indeed, extraordinarily they vary; I should not like to say, between 20 and 100.

7082. So much as that?—Yes.

7083. Even in ordinary dry weather?—Yes.

7084. That has largely to do, I suppose, with the chemical refuse and iron?—Yes, it is parallel with the other variations that we find in the strength of sewage at different hours of the day. Of course, the presence of road detritus is limited almost entirely to periods of rain.

7085. And the average suspended matter you take as 32?—No, I have stated in one case it was 44; that was the average over 19 months, but an average over a longer period reduced that to about 42.

7086. Is that an average of daily observations during 19 months, or several observations made in the course of the same day?—It would be based in some cases upon observations made in different parts of the same day, but the average was an average obtained from a very large number of analyses.

7087. And the average would be somewhere about 44?—I should say so, roughly, but the variations are very great.

7088. Very great?—I should think the permanent average for Leeds would not be so high as 44; it might be somewhere between 40 and 44.

7089. (*Major-General Carey.*) Have experiments been made at Leeds to ascertain the result of continuously working the filters in spite of the reduction in capacity—working them to the end?—Well, we did not work them to the absolute end, but we worked our No. 1 and 2 beds until the capacity was reduced so far that it seemed to us that there would be no object in continuing it further, because the quantity per acre that would be passed would be so small as to make the cost of such filtration prohibitive.

7090. You had no reason to think that a point would have been reached at which there would have been no further reduction in the capacity owing to the improved condition of the bacteria bed, and that the same volume of sewage could have been passed through it as when the bed was first matured by increasing the rate of flow?—I think probably that a point would be reached when the capacity would not be reduced to a further important extent, but that would be when the volume which could be passed through the bed was so small as to make such filtration, from the point of view of cost, impracticable. I do not think that it would be possible when such limit is reached to increase the number of fillings to an important extent. If you did that, you would get a bad result, and you would get then a much more rapid reduction of capacity.

7091. You do not think that by increasing the number of fillings the increased rate of flow through the filters would produce the same results as you get in the first instance, even when the loss of capacity was very great?—It can be done, but it is at the cost of capacity reduction.

7092. As to the depth of filters, have you formed any opinion as to the limit of depth that you consider most efficient?—Our experience of course has been limited to the beds we have had at Leeds, and our deepest bed was 6ft. So far as our experience goes, the greater depth gives a better result, but I am unable to say from actual experience how far increase of depth beyond 6 feet would give improved results or the contrary.

7093. Then as to the treatment of storm water in filters, do I understand that the storm water, say up to 5 dilutions, could be passed through a bacterial filter which was designed to treat the ordinary sewage at 3 fillings a day, or do you increase the area of a filter in which you intend to treat the storm water so as to have only one filling per day?—I think I have said in some parts of my evidence that I think it is desirable, if practicable from the point of view of cost, to give only one filling a day for the normal flow, so as to be able to increase the number of dilutions upon the bed up to 6, without seriously affecting the condition of the filter. But it is right that I should say that at Leeds we have not been able to try experiments with dilutions on filter beds. I think it is quite practicable to increase the number of fillings when the sewage is dilute. The results, of course, will be less satisfactory in percentage, but inasmuch as the impurities are also less in the sewage being dealt with, the result, although the percentage upon such impurities may be less, may still be good enough.

7094. Then, whenever that limit of storm water has been suddenly passed through an ordinary bacterial filter, would not the effect be to prevent the efficient action of the bacteria bed for the treatment of the ordinary sewage?—I do not think so. The reduction of the period of aeration would temporarily affect the working of the bed, but if it were not long continued I do not think it would produce any lasting evil effect.

7095. You think that the bed would immediately revert to its ordinary condition after the storm had passed?—Yes; as soon as the normal periods of rest were given to it.

7096. (*Professor Ramsay.*) You do not suppose the bacteria are washed out of the bed by ordinary storm water?—No, the effect of passing storm water over a bed is merely to reduce the period of aeration. If that was continued for any long period, I think in all probability it would destroy the efficiency of the filter. If continued for some hours it would produce no lasting evil results.

7097. (*Major-General Carey.*) You think it would be quite safe to pass storm water, 5 volumes, through an ordinary bacteria bed designed to take three fillings, worked in eight hours' system?—I scarcely think that; I do not think that would be a good plan to adopt, because the first dilution is usually quite as bad or worse than the ordinary sewage, and I do not think that it ought to be passed at the rate of six fillings over the bed. The result would not be satisfactory.

7098. I mean storm water?—Yes. But the first dilution of storm water is usually very bad, and I think the area ought to be such that one dilution can be passed over contact beds at a rate not exceeding three fillings a day. After that no doubt you may increase the number of fillings, because the impurities are greatly less.

7099. You designed the bed really to take four volumes, say, three times the dry weather flow. The bed would be able to take four times the dry weather flow in three fillings a day, to enable you to pass the excess water?—According to my last answer, the bed ought to be designed for 1½ fillings a day, normal flow, so that when you had got one dilution you would not exceed three fillings a day.

7100. With regard to the continual loss of capacity, you have not made any experiments with purely domestic sewage on contact beds?—We have had no opportunity at Leeds.

7101. (*Professor Ramsay.*) Can you tell us the average amounts of suspended and soluble solids in the Leeds sewage?—Yes, we have all the data.

7102. Are they given. If not, perhaps Mr. Harrison will make a note to put it as an appendix in the report?—(*Mr. Harrison.*) The average suspended solids are about 42 grains per gallon, and the soluble solids will be between 60 and 70; they vary slightly.

7103. What are the suspended solids composed of?—(*Colonel Harding.*) You mean, the relative composition, mineral and organic.

7104. Mineral and organic?—Roughly, 60 per cent. organic, 40 per cent. mineral.

7105. Has cellulose been identified at all as forming part of the suspended solids?—I have not personally given attention to that point.

7106. Do you know, Mr. Harrison?—(*Mr. Harrison.*) I have never identified it.

7107. No microscopic examination has been made?—Oh, yes; you can see fibres by a microscopic examination, but I never identified it in the actual sludge.

7108. Have you any idea of what the soluble solids are composed?—(*Colonel Harding.*) I think these are questions perhaps Mr. Harrison will answer later on.

7109. Can you give us any idea, Mr. Harrison, as to what the soluble solids are composed of?—(*Mr. Harrison.*) There will be about 60 grains of mineral matter, and 10 grains of organic matter.

7110. You refer to the utilisation of sewage sludge by making it into briquettes; has that been practically tried?—(*Colonel Harding.*) Not by us. The plant is to be erected; it has been ordered, and is about to be put up at the Leeds Sewage Works for the purpose of enabling us to test that ourselves. Tests have, of course, been made by the inventor of the process, who says that valuable fuel results are obtained from briquettes so manufactured; manufactured, I think, to the extent of about one-third of their composition of sewage sludge. I am unable, myself, to express any opinion upon it, because I have not had any experience of such manufacture, but we shall very soon have such results, because the plant is about to be put up at Knostrop to produce about 35 tons a day.

7111. Would you pay those people for disposing of your sludge, or would they take it free?—They would take it free, and we should be very pleased indeed to supply them with any quantity free of cost.

7112. Do they propose drying it, or do you?—They propose to dry it, and mix it with coal and other ingredients, a kind of mineral oil, I believe, and sell it in the form of briquettes, which we have tried. We have tried the briquettes, and have found them to give satisfaction.

7113. It depends entirely on the proportion of coal dust and tar?—I have suggested to them that probably the same results would be obtained if the briquettes did not contain any sewage at all, but the inventors say there is a fuel value in the sludge, and that the briquettes are worth more with the 30 per cent. of sludge in them than without. I am quite unable to express any opinion upon it from personal knowledge.

7114. Can you tell us how they are going to dry the sludge?—I do not know.

7115. Is there any means of getting to know this, or shall we have to wait?—I am afraid it would be neces-

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sary to wait, but very shortly we shall have the plant, and we shall then be able to give you the fullest information about it.

7116. Then, in answer to another question, you state, "the samples of specific trade effluents were also sent to him, namely, iron liquor and tan yard liquor. In reference to these he found that in dealing with the iron liquor by itself there was at first considerable oxidation of the iron salts, but this result was obtained at the expense of the efficiency of the beds, which soon became unfit for further work." Well, is it supposed that the iron takes up oxygen which would otherwise go to nitrification?—That is so, which would otherwise go to the oxidation of organic matter.

7117. Has that been proved?—In that answer I am relying upon the report of Mr. Dibdin himself. The experiments were made by him in London, and I have no personal knowledge of them.

7118. In answer to another question you discuss the relative value of coke and clinker as materials for beds, and you say that if the materials are used under equal conditions as to depth of beds and size of the material, good results should be got. Do you think the specific nature of clinker has to do with the retention of the iron it contains?—I do not think there is much disintegration of clinker, there is some disintegration of coke; clinker is harder, and it disintegrates to a less degree.

7119. You do not think it is chemically attacked by the sewage?—I do not think so from the facts which have been brought to my knowledge; it is a point I have not investigated.

7120. Does Mr. Harrison agree with that?—(*Mr. Harrison.*) Clinker is attacked by the sewage; in fact, on first starting a bed filled with fresh clinker, it has been found that a great deal of solid matter goes into solution, chiefly common salt, I believe, and if this goes on for any period the surface becomes brittle, and pieces fall off, and we have been able to find them in the effluent from the No. 2 Whittaker bed.

7121. Do you think that it is in any way connected with the possible reduction of the iron in the clinker?—Do you mean the removal of the iron from the sewage?

7122. No; I mean the reduction of the iron in the clinker. Clinker contains a quantity of iron?—I do not think that is the case. Of course we found practically no iron in the filtrates of many material beds.

7123. Then it is a washing out of the soluble matter of the clinker?—Yes.

7124. Has such a substance as shingle been tried by you at all?—(*Colonel Harding.*) No.

7125. Nothing smooth?—No. We are too far from the sources of supply.

7126. It would not pay?—It would not pay.

7127. In your answer to another question your experience in view of deeper beds strikes me as curious. I see you expected to find that in shallower beds you would get some aeration?—My own idea was that by having shallower beds you would probably be able to pass a larger volume of sewage through them than through deeper beds, and that would be much less costly to construct. The idea, therefore, was that the periods of aeration could be reduced, and so the number of fillings increased, and I was much disappointed to find that that result was not obtained.

7128. It is a very disappointing result—I mean what you have got?—It certainly disappointed me; I expected to find that we should get better aeration, and that we should reduce the periods of aeration, but we do not find that.

7129. Have these experiments been made on an extended scale, so as to make perfectly certain of the deduction?—Beds 3, 4, 5, and 6 are all of the shallower depths, and they have been worked for long periods—2 years. We never, in fact, obtain results so good as we do with deeper beds—1 and 2.

7130. Is there any reason for it?—I am unable to account for it. It was quite contrary to our expectations.

7131. Is it conceivable that the temperature of the deeper beds is higher, and that there is a lesser draught up?—We have careful records of the temperature. Mr. Harrison reminds me that it is not greater in the deeper beds than in the shallower.

7132. It is a very important question as regards levels, is it not—as to whether deep or shallow beds should be used?—Very.

7133. And it is a question which would require thrashing out to see whether it was always the case, unless you consider your present experiments as satisfactory?—No, I should not think our present experiments conclusive on that point. I should think certainly any conclusion ought to be based on wider data. It is a point that requires investigation.

7134. Is it not one of the most important points? Because in many cases the difficulty in disposing of sewage is want of fall, therefore a shallow bed might be used and a deeper one could not without pumping.—It is a most important matter; no doubt land treatment may be used in such a manner as to be the same as using very shallow beds covering a large area.

7135. Quite so?—Where your area is valuable the same results could be obtained by using a greater depth of material by artificial filtration. It is largely a question of local circumstances and engineering. If I might just on that point remind Professor Ramsay that Mr. Fowler, of Manchester, has tried a shallow bed 15 inches deep with good results.

7136. Yes, I remember that is so. Coming to the questions as to the method and rate of filling the contact beds, does the clogging up of the bed not depend very largely on the rate at which the bed is filled? I mean destruction of the bed itself will take place if there is rapid filling, owing to the exhausting of the top layers?—I do not think the speed of filling affects anything more than the settlement on the surface of the bed; I do not think it affects the body of the bed.

7137. Even when it is continued over a long time?—I think if the filling were very slow probably the solids would percolate down into the bed more easily than if it is rushed upon the bed, in which case probably there will be more settlement on the surface.

7138. Is there anything like a pumping action when the bed is emptied rapidly and stuff drawn in from the top into the body of the bed?—No, because the speed of emptying is so slow that the suction downwards will not be very great.

7139. That has not been noticed?—I do not think it would be very important, the suction would be very slight.

7140. But when you fill a bed quickly is it not the case that most of the liquid that runs out of the bed spreads over it?—Yes.

7141. Whereas, if you fill it slowly it runs pretty much into the point of first contact?—If you run very slowly it would nearly all go in there.

7142. You do not attach importance to the distribution of the effluent on the beds?—It is a very important point indeed.

7143. Do you regard the distribution as better if the bed is filled quickly than if it is filled slowly?—I think it is better to fill quickly because you get conditions which are more equalised between the top and the bottom of the bed. Filled very slowly you get most unequal conditions, and the bottom part of the bed is scarcely aerated at all. Personally, I favour rapid filling. The disadvantages arising from rapid filling owing to surface mud seem to me to be minor difficulties.

7144. Have actual experiments been made to see the comparative rates of purification, of slow and rapid filling?—No, not by us.

7145. It could be done?—Yes; but I should expect this result, that by slow filling you would get worse results than by rapid filling, because the aeration of the lower parts of the two would be ineffective.

7146. I do not quite see why?—Well, suppose you took four hours to fill a bed.

7147. Yes?—Then the upper part of the bed would be aerated four times as much as the lower part, and if you took four hours to empty it you would double those results.

7148. That is to say, that the lower part of the bed would not be exposed to air for nearly so long a time?—The lower part of the bed would be scarcely exposed to the air at all.

7149. Owing to the long time taken in filling and emptying?—Yes, it would be almost permanently water-logged.

7150. You have practically in your answer to a pre-

vious question settled this point. You began by an elaborate system of troughs filled with holes, but you found the troughs constantly silting up with sludge, and the holes very soon stopped up. That would mean slow filling, would it not?—No, the filling then was at the rate of about 1 hour, but we found great inconvenience arise from the settlement of sludge in the troughs, and the filling up of the holes, and they required constant attention.

7151. The sewage was run on to the beds as quickly?—Just as quickly.

7152. As in the old case?—Yes.

7153. With reference to your answer to the next question, I should like to ask if you have any analytical results of shorter or longer periods?—We have the analytical results, Mr. Harrison will give you them. At first it seemed as if the four hours contact gave an improvement, but continuing the experiments we did not find that there was any improvement worth varying the period of contact for. (*Mr. Harrison.*) The experiments are detailed on page 50 of the Report.

7154. Thank you, that will be quite sufficient. The method of sampling in Leeds, how has that been done? Has it been done according to the rate of the flow?—(*Colonel Harding.*) No, it has been done at periods of ten minutes interval, ten minutes at the start and then every ten minutes for one hour. No doubt the result is not proportionate to the flow because the flow is more rapid at first than at the end, but you have to set against that the fact that a contact bed goes on trickling for hours and days after the hour of main flow has been completed, and that the best results are then obtained during such trickling and filtration. That, I think, may be fairly set against the fact of the low rate during a portion of the flow, and I think that, although samples are taken every ten minutes, irrespective of the speed of the flow, the samples are fair samples for the experiments.

7155. The only question is as regards the comparison. The analytical results ought to be rather better by taking it as you have taken it?—The analytical results are better no doubt taken as we have taken them, but in that case in order to get the correct results it would be necessary to add a certain proportion of the trickling filtration which has been left out of the account altogether, and that I think would to some extent equalise those results.

7156. The effluent from the Leeds filters runs into your very black river I presume?—Yes.

7157. There is no use investigating the state of the river, I suppose?—The river at Leeds may be just looked upon as a septic tank, 8 miles long and 100ft. wide, for the treatment of the sewage of Bradford.

7158. I forget what is the distance from the works to the river?—About a couple of hundred yards.

7159. There are no other works on the channel?—Yes, that channel is swamped by the effluent from the lime precipitation, but there is a channel from the contact beds about 100 feet long, which is available for examination.

7160. When you speak, for example, in answer to a question put to you by the Chairman, of this effluent being rarely liable to subsequent putrefaction, is that deduction drawn from the behaviour of the effluent in that channel?—To some extent that is so. We have only noticed in that channel green growths, and no sewage fungus, but our results are obtained from actual experiments in the incubator.

7162. (*Mr. Killick.*) I understand that we are now dealing with the question of the treatment of slowly settled sewage on contact beds?—Yes.

7163. It would be necessary clearly to distinguish between the filter dealing with thoroughly settled sewage and partially settled sewage.

7164. (*Professor Ramsay.*) It might be convenient to take that question later?—I think it would be better in some respects to take it now in connection with the contact beds. There can be no doubt that the question is affected very much by the amount of suspended solids in the sewage which is being dealt with, and our experience in Leeds, in double contact beds, and my answers in this examination relate to the treatment more or less of crude sewage upon the contact beds and not to the treatment of the septic effluent upon contact beds. I think in my later answers I have made some reference to the treatment of septic effluents upon double contact and single contact beds, but I have avoided speaking with any confidence of the results of those experiments, because our experiments of double contact beds with septic effluents have not been carried on sufficiently long to warrant our drawing any strong conclusions. All my answers refer to the treatment of more or less crude sewage upon contact beds.

7165. I am going to ask you about that. Does the rate of sludging up by crude sewage depend upon the size of the material of which the filter bed is made?—The size of the material affects the question in this way, that if the material is fine they are mechanically kept back on the surface, and it was found that with crude sewage upon the fine bed we could not work more than a very few days before the surface of the bed was completely choked with suspended solids. We found, from using a coarse material for our coarse bed, we were able to continue working the bed for a considerably longer time.

7166. Did grading the material affect the results?—The grading of the material is important in my own idea, but not for that reason—the grading of the material seems to me to be very necessary. The material should be of equal size. If you use material of unequal size on a contact bed the effect of filling and emptying is by gradual movement of the material to fit smaller pieces into spaces between larger, and so to bring about consolidation and consequent reduction of capacity. I look upon it as a most important thing that in a contact bed or in any filter bed the material should be of equal size. If the material is of equal side I believe the capacity will be the same whether the size be large or small.

7167. Then you regard the reduction of the capacity partly as due to the shifting of the material?—I do. I regard the reduction of the capacity in our experiments at Leeds as in a large part due to consolidation, owing to the material not being equally graded.

7168. Then did the level of the beds drop?—The level of the beds dropped to some extent. We found that after a while it was necessary to put in additional material to bring them up to the same level.

7169. Would that process go on for ever, or does it not stop at a certain point, in your experience?—It goes on undoubtedly until at last you obtain, as in beds 7 and 8, such a condition of consolidation that it is no longer practicable to work them. We found in beds 7 and 8 that the capacity was so far reduced that we could not work the beds. We then did not screen the material or wash it, but we simply turned it over from the bottom, completely over, loosing it, and we then started again with the original capacity. We practically regained the capacity, but rapidly the material settled again and consolidated.

7170. You regard loss of capacity as wholly due to the alteration of the structure of the material?—I look upon it as very largely due to the alteration of the structure of the material. To a great extent that the material was unequal in size, and that the gradual lifting and falling of the material tended to fitting in the smaller pieces.

7171. Would not the rate of filling the bed affect that to a large extent?—Not to any material extent.

7171*. No occasional disturbance in the filling of the bed?—The disturbance is quite local in the neighbourhood of the in-flow. Within a few yards of the in-flow there is a surface disturbance, but the main body of the bed is not affected by the rate of flow.

7172. Dr. McGowan suggests that I should ask whether any comparative examinations have been made of the nature of the solid material going on to the rough and fine beds?—Yes, we have analyses of the suspended solids in crude sewage, and the suspended solids in the filtrate from the rough bed, if that is what Dr. McGowan means?

7173. (*Dr. McGowan.*) Yes?—We have analyses.

7174. I meant rather close examination, not merely a question of so much organic and so much mineral matter—anything more like that?—I think not. (*Mr. Harrison.*) No.

7175. (*Professor Ramsay.*) Still, with regard to another of the questions put to you, your second contact beds maintain pretty near the same capacity, do they not?—(*Colonel Harding.*) Yes there appears to be no loss of capacity in fine beds to give us cause for anxiety, but it is fair to remind you that the volume of sewage put upon the second beds was constantly being reduced by the reduction of capacity of the first bed, and that therefore it was only at the beginning of their working

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that they got a full dose; but I do not expect there would be in any case very much trouble with the reduction of capacity of the fine beds, because they receive suspended solids to a smaller extent relatively.

7176. The average solids in suspension going on to Nos. 2, 4, and 6 beds respectively, are 12·2, 11·3, and 14·3 grains?—Yes.

7177. So that they do not differ much?—Not very widely, but that of course is greatly less than the suspended solids going on to the rough beds. It would be from about a third to a fourth.

7178. Is it not the character of the solids that differ rather than the amount of the solids?—The amount differs, and, I think, the character.

7179. Is it not possible that the cellulose matter in the bed which clogs it is removed after passage through the first bed?—I should think that is so. The solids which reach the fine beds are in a more reduceable condition than those that come to the first bed.

7180. And that would account for the non-clogging of the second beds?—I think so.

7181. Do you know if the solids in suspension which issue from the second contact beds are putrescible when they are separated from the effluent. Can Mr. Harrison tell us?—Those experiments with contact beds were almost completed before Mr. Harrison came to us, and I do not think we have made any experiments to ascertain the putrescibility of the suspended solids in the final filtrate in the contact beds.

7182. One would imagine that the final filtrate in the contact beds would be of an albuminous nature, and from the first beds of a celluloid character—paper, and stuff of that sort. I wonder whether the stuff that was retained by the second beds was putrescible owing to its character?—That was retained?

7183. The suspended solids?—That came out in the filtrate?

7184. That came out?—I am unable to answer the question. I should think it likely that they would be non-putrescible.

7185. Is the first flush of effluent from the second contact bed putrescible?—The first flush would certainly contain putrescible solids.

7186. As it always does?—Yes.

7187. Is it not possible that a certain loss of capacity comes from the very large amount of water which is retained by the sludge?—Yes, every grain of suspended solids in the filter holds up nine grains of water with it, and there is no doubt that the loss of capacity largely arises from the fact that the filter does not empty. The material on the surface of the coke retains and holds up a certain quantity of liquid.

7188. Is that a true loss of capacity?—It is practically a loss of capacity.

7189. In filling and emptying?—That is so. After reasonable periods of aeration the bed does not empty.

7190. We have got very much the same thing in our own lungs. We do not completely empty our lungs—only partially. We take in a breath; there is an exchange going on between carbonic acid and oxygen, but the change goes on equally well—just as well as if we were to empty our lungs altogether?—Yes, only you add solids and accumulations of the bed; and these retain additional liquid.

7191. Is not that liquid exchanged for the fresh liquid which goes in?—Very likely, but an increasing quantity of liquid is being retained. As the accumulations increase the spongy matter is increased, and therefore an additional quantity of liquid matter is kept back, and if the period of rest is the same, say, four hours in a cycle of eight, then in that four hours increasingly less liquid comes out, and more is retained in the bed.

7192. And increasingly less oxygen gets access to the liquid, I suppose?—Yes.

7193. That is the main difficulty. In another of the questions put to you, you discuss the question of the digestion of the suspended solids in your bed. Is it possible to get definite data as regards this digestion?—I think the answer given to the question to which you refer is based upon insufficient data, namely, one experiment, to warrant anything like definite conclusions.

7194. Are any experiments being made of the kind?—No, it seems to be very difficult to ascertain the amount of digestion of suspended solids by contact beds.

7195. But you believe that digestion does take place?—Oh, I think undoubtedly digestion does take place, but I am afraid it may exaggeration to say that it extends from 60 per cent. to 70 per cent. I think, probably, it would be found to be, judging from what has been done by septic tanks not quite so large, between 50 and 60 probably.

7196. I was just going to ask you, do you think it is as effective as a septic tank?—I do not see why it should not be as effective.

7197. One is aerobic and the other anaerobic. Is not an aerobic process better than the anaerobic?—The data we have would seem to show that as good results were obtained by aerobic as by anaerobic change, this experiment upon this rough bed referred to in my answer, you see, gives results which are somewhat over those which have been obtained by anaerobic action in septic tanks.

7198. Do you think that after the digestive action has gone in a septic tank from the beds which are used, that the effluent from the septic tanks would also go on digesting any sludge that might be carried over to the septic tank?—To some extent no doubt just as if those solids which go out in the effluent were retained in the tank itself. I see no reason why some proportion of digestion should not take place in regard to those, as in regard to those left in the tank.

7199. Unless it was held that the substance that escapes from the tank is indigestible?—But that is not so. We find that the analyses of the suspended solids coming out of the septic tank is the same as that of the sludge, namely, one half mineral and one half organic.

7200. Still it is a question of what is the nature of the organic matter. One might be digestible and the other not?—Yes.

7201. You make a very important statement in the end of your answer to one of the questions addressed to you by the Chairman:—"But I have come to the conclusion that for Leeds sewage the system of intermittent or contact filtration is impracticable, although good filtrates are certainly obtained." Are you quite convinced of that, absolutely?—So far as the treatment of crude sewage upon contact beds is concerned I am quite satisfied that it would be impracticable for us to do it, because of the very large and very costly area of the beds which would be required.

7202. Would introducting septic tanks reduce the area of those beds very materially?—Yes, the reduction of capacity would probably be considerably less.

7203. But including the area of the septic tanks and the area of the beds together, is the total area of land covered reduced?—I have not calculated out what the relative area would be, but I should think it probably would be considerably less with septic tanks, and I think the cost of septic tanks would be distinctly less than the cost of filters.

7204. Would you take into account also the necessity of repairing the filters if they are used for intermittent filtration, in comparison with the cost of filtration in connection with septic tanks?—Repairing filters?

7205. I mean renewing the material, and so on?—The cost of renewing material or sorting material would obviously be very much greater if you are dealing with crude sewage than with septic tank effluent, because choking would be very much more frequent and sorting would be very much more frequently necessary.

7206. Can you give any definite numerical statement, or have you formed any in your own mind which would enable the whole question to be gone into from a pecuniary point of view?—It is a subject which, of course, we have carefully considered in connection with the proposed treatment of the Leeds sewage, and we have based our opinion upon the results which we have ascertained. We found that in dealing with crude sewage the capacity was so far reduced that in order to maintain it, it was necessary to work the filters at such a slow rate that an immense area would be required, and the cost of filtering material and the construction of filter beds was very great. We concluded that this system of treatment would be impracticable for Leeds; that it would be better to reduce the area of the filters by introducing some preliminary treatment with the view to reduce the amount of suspended solids to be dealt with on those filter beds.

7207. It appears to me that there are two questions, first of all with regard to the extent of the land to be covered, secondly the amount of work to be spent upon

the filters. Taking that first, do you think that the area of a septic tank, plus filtering beds would be less than the area of a filter bed if the crude sewage were turned on?—Yes.

7208. Secondly, that the cost of turning up the filter beds which had crude sewage run on in order to get the required rate of filtration, would be very much greater than the cost of turning up filter beds when the filter bed succeeded the septic tank treatment?—Undoubtedly.

7209. I get to the fact that in the first case they would often require to be turned up and renewed, and in the second case they would not?—Yes, in the first case we satisfied ourselves that it would be far better to have a preliminary process for reducing the amount of suspended solids to be dealt with on the filter than to deal with the whole of them on the filter. The filter acts very readily on dissolved impurities, but very slowly upon suspended impurities.

7210. Dr. McGowan reminds me that in answer to another question put to you by the Chairman you say Sheffield is an instance of treating crude sewage on contact beds, but the first beds have clogged up badly, and the management thinks of abandoning this treatment?—I have no knowledge of that. The last time I heard anything of it the members of the Sheffield Corporation came to Leeds, I think, some six or eight months ago, and they told me that the analytical results were extremely good, and I satisfied myself when I was at Sheffield that that was so, and I have also seen the report of the Rivers Board upon it. The results are good, but there was no information of any kind of the reduction of capacity. They had no means of testing the capacity. The beds were banked up with earth, and there was considerable leakage, I believe, of the sewage that went into the beds, and there was no means of testing it. I pointed out to the deputation that came to Leeds how important it was before they entered upon any considerable expenditure in that direction that they should satisfy themselves as to where the capacity was or was not being reduced. They appreciated the importance of that, and said they would endeavour to do so, but so far as their experience had gone, judging from the time it took them to pump to fill the bed they had not noticed any material reduction of capacity. I have no knowledge of their finding that they have choked up the beds, though I should not be surprised if that result had been obtained.

7211. Perhaps Mr. Frye could tell us that?—(*Mr. Frye.*) I went to Sheffield last Monday, and the aeration beds were very bad indeed.—(*Colonel Harding.*) I foresaw that result.—(*Mr. Frye.*) And the chemist told me that he would not advise a scheme at all where the sewage was not subjected to preliminary treatment.

7212. (*Dr. Russell.*) I suppose this question of capacity is a very vital one in its bearing on the practical value of filtration?—It is, of course, a vital point in regard to the question of expenditure and maintenance.

7213. I am very much interested with the conclusion of an answer you gave to a question put to you by the Chairman, in which you say:—"If a material can be found for contact beds of even size, and not liable to reduction, the life of the beds would be greatly lengthened, for loss of capacity is due I believe more to reduction and consolidation of the material of the bed than to the undigested matters brought down by the sewage," and then in your last sentence you say "the question of the material which can practically be used is necessarily dependent on local conditions," and your contribution now is wholly what has been your local experience on the material available?—Certainly, I have in this examination limited my answers to Leeds experience.

7214. So that it would be of great importance for the Commission to have experience with other material which is economically available in other localities with reference to this question of loss of capacity?—Yes, the experience I think is available. There have been many instances in which burned clay has been used, and in which cobble stones have been used, for instance at Southwold I think they have filtering beds made of fine cobble-stones, and there are instances in different parts of the country where varieties of materials have been used. Personally I do not think it matters anything from a chemical point of view what the composition of the material is, but it matters exceedingly what the size of it is, and the durability in regard to degradation.

7215. So that it would be possible from a theoretical point of view to form an ideal of what would be the best filter material?—I think so. My own idea would be spheres sufficiently hard to maintain their form.

7216. But practically it would come to be what material nearest approaching this ideal is available in the particular locality?—Yes, the important thing seems to me to be that the material should be of equal size.

7217. I think Professor Ramsay spoke about gravel; that would come pretty near?—Yes, if it were of equal size.

7218. If it were of equal size, that is the trouble, and you thought granite chips also, although of no use to you, might be if they were available?—I think so, if it were not in the form too much of slabs; if it approximated to the cubical form or to the spherical form.

7219. There is a sort of granite meal which is used for repairing road purposes; I think it is made mechanically by the machine grinding granite—that would be good?—I think where a fine material could be used that would be very good. Of course, the advantage of granite would be that it is not easily reducible.

7220. Then it is of importance that it should not be friable?—I think that is very important.

7221. And it would be important that you should get something which was not friable and which was yet porous?—I do not think the porosity is very important.

7222. You do not think so?—No.

7223. Not in extending the area?—I think with pieces of coke which is very porous, the pores are permanently filled with liquid, and the action is very much the same as that of the surface of a rounded pebble.

7224. And chemical constitution would come in in a measure, as it does in connection with this iron question, but that would only be in the rarer conditions with manufactures—I suppose trade effluents?—I do not think that the chemical constitution of the material is very important. I think it is more mechanical conditions than chemical which affect the question.

7225. You think that the ideal is equally sized gravel?—I think equally sized gravel would do very well.

7226. (*Mr. Killick.*) You have put your evidence so admirably before us that I only want to ask a few questions to emphasise the conclusions that you have come to. All these experiments we are now dealing with on contact beds are on virtually crude sewage?—That is so.

7227. And you have come to the conclusion that in Leeds it is impracticable to treat crude sewage on two contact beds?—Yes.

7228. On account of expense?—Yes.

7229. Of course, that would not apply to the treatment of thoroughly settled sewage on contact beds?—No.

7230. You do not condemn that?—No, if you are dealing on contact beds with thoroughly settled sewage I think that you would bring about conditions that would make it very possible indeed to work for many years without choking the filter?

7231. And there would be, of course, a great difference in the treatment of sewage in the case of a town where the sludge could be sent to sea?—Yes, where there are facilities for sending the sludge to sea it may be well worth while even to chemically precipitate the suspended solids so as to pass upon the filters a liquid containing merely dissolved impurities.

7232. And the figures you have presented to us of the loss of capacity on contact beds of course refer to the contact beds treated with this virtually raw sewage?—Yes; and I should like, if you would allow me, just to remind the members of the Commission that although many of our experiments were with screened sewage, it was in effect crude sewage although screened, because the matters screened off do not usually come into the analyses. The amount of finely divided solids would be almost the maximum amount, although the sewage was screened—of course, tea leaves, corks, matches, and little bits of paper and so forth do not come into the analysis usually.

7233. And the experiments in other places which lead us to believe contact beds ought to lose between 35 and 40 per cent. of their capacity and remain constant, of course, are not affected by these experiments of yours?—No, but I must say I doubt the possibility of permanently maintaining the capacity unless what is put upon the filter beds is almost wholly free from suspended matters. My experience at Leeds shows that the suspended matters are to some extent reducible,

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probably to the extent of 50 per cent. They are reducible, and if fine filters are used, and these irreducible matters do not come out, they must of necessity remain behind, and ultimately possibly at long periods, if there are not very many of these solids, bring about accumulations in the bed.

7234. Take the case of the Roscoe beds at Manchester, with which I think you are acquainted?—Yes.

7235. They think that after five years they are maintaining something like a uniform capacity?—But what they have been dealing with on those beds is thoroughly settled sewage.

7236. Exactly?—Containing, I think Sir Henry Roscoe told us, only about 3 grains of suspended solids per gallon, you may almost say sewage, free of the suspended solids.

7237. In those beds they have observed a piling up of the surface. Have you observed anything of the same kind at Leeds?—No.

7238. Have you any information as to the cause of it?—In Manchester I should think probably there would be some ultimate accumulation of irreducible matters, and these irreducible matters would become added to the body of the filter, and so gradually raise the level of it.

7239. Yes, that the irreducible matter that goes on to the filter which causes you so much trouble may under certain circumstances appear at the top of the filter?—Yes, on a fine filter it would probably be kept back on the surface.

7240. And that matter being taken out and dried and put back would make for the life of the filter?—Well, if these matters were not in a finely divided form, if they aggregated into little lumps, I think it is possible they might be considered as being added to the material of the filter, but I am rather sceptical of the permanent life of any contact bed. It is a mere question of time and practicability that I think ultimate accumulation must arise if there are any suspended solids going on at all.

7241. Of course, upon the life of a filter depends the cost of the treatment of the sewage?—Yes.

7242. And therefore it really becomes a matter of calculation as to the advisability of adopting some system after it is once proved that by that system you can get a satisfactory result?—Quite so, it is a question of practicability.

7243. (*Chairman.*) Let us now pass on to the septic tank experiments. Your object in these, I suppose, was to find some preliminary treatment of your sewage which would facilitate filtration by withdrawing a considerable part of the suspended solids?—Yes, and we hoped that the solids so withdrawn would to a great extent be disintegrated and changed to liquid and gaseous products by the anaerobic action of the septic tanks.

7243* On what scale were these experiments?—On a scale sufficiently large to be considered practical. We have been dealing with over two million gallons a day in various septic tanks.

(*a*) We had first an installation upon designs submitted by the Cameron Syndicate at Exeter, and consisting of two covered septic tanks each 54ft. by 10ft., and 9ft. deep at deepest end. These were connected with six filter beds, some of coke and some of clinker, by means of automatic filling and emptying gear, and dealt with 40,000 gallons a day.

(*b*) Then we had a series of open septic tanks on a larger scale. The tanks, Nos. 1, 2, and 3, had each a capacity of 250,000 gallons, and were worked independently at different speeds of flow.

(*c*) We had also a tank in two compartments, with a joint capacity of 500,000 gallons, and, (*d*) finally three tanks working in series and having a joint capacity of over one million gallons.

7244. How long have these experiments been going on?—The No. 1 septic tank was started on February 27, 1899, and all the others within a few months after, and they have been working ever since, that is, from 1½ to two years.

7245. What opinions have you formed of the relative value of open and closed septic tanks?—The question whether septic tanks should be closed or not is of importance in view of the considerable extra cost of roofing them in. The advantages claimed for closed tanks are:—

(1.) That the roofing excludes the air from the surface and promotes better anaerobic conditions.

(2.) That the resultant gases are under control, and can be utilised for lighting or heating.

(3.) That evil odours are prevented from escaping.

(4.) That the heat of the sewage is better maintained.

The experience of Leeds shows that whatever results were obtained from the closed septic tanks were equally well obtained by the open, and that the scum which forms on septic tanks, itself soon gives a cheap automatic roof, which is chiefly of value in preserving the heat in the sewage, the floating surface being a bad conductor. It was found that the average loss of heat of the sewage in passing through the open septic tanks was 1·6° F., while through the closed it was ·8° F., and the difference is too small to warrant the expense of a roof on this account. The heating value of the gases is not great, and the roofed-in septic tanks are really gas holders, and except under proper care, may become a serious source of danger. In the open septic tanks the gases produced are at once dispersed. For the most part they are inodorous, no appreciable nuisance having arisen, though the effluent itself is more or less offensive. But Leeds sewage is diluted and mixed with trade effluents, and no doubt where strong domestic sewage is being treated, greater nuisance may arise, and the roofing become necessary, though it would only be effective if the gases were burned. In appearance the effluents obtained from the open and closed septic tanks were identical, whilst from a chemical point of view no distinct difference can be detected.

AVERAGE of ANALYSES referring to Effluents from Open and Closed Septic Tanks.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).
Effluent from OPEN Septic Tank (No. 1) -	77·6	13·1	1·83	·455	4·18
Effluent from CLOSED Septic Tank (No. 1) -	77·9	12·8	1·8	·437	4·82

7246. Describe to us briefly the development of action in a septic tank?—When a septic tank is first started, a simple settlement of suspended matters takes place, and the effluent is similar in colour to the sewage, being in fact mere settled sewage. Several weeks pass before there is in Leeds sewage any fermentation in the tanks. Then bubbles begin to arise, slowly at first, and after two or three months more actively, until about the fourth month accumulations of gas in the deposit come up at intervals with considerable violence, lifting with them masses of the black deposit to the surface. Most of these, liberated of their gas, go down again, but some float supported by gas, and become entangled with light floating matters such as corks, matches, etc. These are driven by the wind to one side or corner of the tank, and form a scum, which gradually spreads over the tank. Exposure to air and sun hardens and dries the surface, which becomes to some extent impervious, the gas escaping here and there through cracks, and deposit brought up from the bottom, held up against the dry upper surface, becomes entangled with it, and so in time builds up a thick floating scum, which may vary from 1 or 2 inches to 1 or 2 feet thick. In the case of strong gales this scum, especially in its thinner form, is often driven by the wind and crumpled up like pack ice, so that portions of dry scum stand out sometimes 12″ or more over the surface. The surface of the scum, especially in summer, is like earth, and seeds falling

upon it soon begin to grow. We have found our scums vary very much, being sometimes sufficiently thick to bear the weight of a man, and at other times disappearing altogether. We found as a rule that they were thinner in winter, but the variation seemed for the most part to be due to accidental mechanical causes. In the covered septic tanks the scum varies much less, as the surface is not exposed to the heat of the sun or the action of wind. Whilst these changes have been taking place in the contents of the tank, the character of the effluent obtained has also altered. At first the outflow has all the characteristics of settled sewage, and at Leeds is yellow in colour owing to the presence of iron. As the putrefaction of the sediment in the tank proceeds, the effluent becomes darker coloured and almost black, and somewhat offensive owing to the solution of some of the products of bacterial action, and the production of sulphides of iron. The gases evolved are inflammable (mostly marsh gas), and no doubt with a sufficient area of covered septic tanks, they might be used for heating and lighting purposes. The effluent contains finely divided suspended solids in varying quantity. With a normal 24 hours' flow the average of suspended solids coming from a new tank was about 8 grains per gallon, but as the capacity of the tanks became reduced by accumulation of deposit the average rose to over 16 grains per gallon, and at times to much more. The average of suspended solids in Leeds sewage is 40 to 44 grains per gallon, so that when the tanks were working well they kept back 80 per cent. of suspended solids, and this proportion was gradually reduced to 60 per cent.

7247. What rate of flow did you find the most effective?—This was, of course, an important point to settle. We tried our first tank at the 24 hours' rate, that is, the flow was such as to fill the tank in 24 hours. We also tried a tank at double this speed, that is, at a 12 hour rate, and another at half speed, that is a 48 hour rate; and when we were working three tanks in series at the 24 hour rate, that is at a rate to fill the three tanks in 24 hours, the speed of flow in regard to the first tank was three times this rate, or such as to fill that particular tank in eight hours, so that we got results of speeds from 8 hours to 48 hours. If the rate of flow is too fast, the tank is a mere settling tank, and becomes full, and requires emptying before septic conditions have had time to develop. The difference between a settling tank and a septic tank is one of speed of flow only. We found that the 24 hour rate was the best, such rate of flow as would fill the tank in 24 hours. Put another way, the septic tank should be of such capacity as to contain 24 hours or one day's sewage. Twice this speed (12 hour rate, or ½ day sewage capacity) permitted septic conditions to develop, but brought away too many suspended solids in the effluent. Half the speed (48 hours' rate, or two days' sewage capacity) gave no better results as to the liquid part of the effluent than the 24 hour speed, and there was too little advantage in the slightly reduced quantity of suspended solids brought away in the effluent to make it worth while on that account alone to double the area of tanks. In one experiment we worked four tanks in series, at the 24 hour rate for the whole, the rate of flow in regard to the first tank being, therefore, a 6-hour rate. At the end of a month, long before septic conditions could fully develop, this first tank was choked quite full with deposit rising in islands above the water level, the sewage flowing in a channel to the other tanks. Briefly, then, my opinion on this point is (1) that any capacity less than half a day's supply is too small to give time for septic conditions to arise; (2) that a capacity of one day's supply is practical, and that larger capacity does not give an appreciably better effluent; (3) that larger capacity, say, two or three days' supply, while not giving much better effluent may probably bring about a rather larger digestion of the deposit left in the tank.

7248. Did you find one shape of tank more convenient than another, a square tank, for instance, have any advantage over a long rectangle?—We tried both, and I don't think that the form of the tank is important. At first the deposit is greatest at the inflow end, but as this accumulates the current carries matters forward, and when fermentation arises and portions of deposit are brought up, they tend in settling down again to move forward with the current. There is then a gradual equalising of the depth of deposit even in a long tank, and if the wind is in the direction of the outlet there will ultimately be more depth of deposit at that end. If the inflow and outflow are so arranged that the sewage cannot flow in a current across the top the shape does not seem very material. If, however, a long septic tank is divided into compartments, or if several square tanks are used in series, the rate of flow being gauged on the total capacity of the series, new conditions are brought about.

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7249. What is the advantage of tanks used in series?—The advantage we expected to find was that we should get an effluent more free from suspended solids, but we were disappointed. It would, of course, be an advantage if all suspended solids could be left behind, for the rate of filtration could then be considerably increased. We found that worked in series, the deposit was mostly in the first tank, and that was the only one that formed a scum. There was less deposit in the second tank, and still less in the third, and these later tanks are likely to go for several years without necessarily removing deposit. By working in series, and the first tank being in duplicate, the removal of septic sludge is facilitated. There does not appear to be otherwise any advantage.

7250. How long have you been able to work your septic tanks without removing any sludge?—Nothing has been removed from any of our septic tanks until quite recently, when we cleaned out No. 1, which had been running nearly two years, and No. 2, which had been running over 1½ years. The sign that removal or cleaning out is required is furnished by the increasing quantity of suspended solids in the effluent. If the flow of a tank is regulated at the 24 hour speed, and later on the tank is half full of deposit, the flow relatively to the available half will be a double flow, and will carry away too many suspended solids.

7251. Then it is clear that at the 24 hours' rate there was not anything like a complete digestion of the solids left in the tank?—No, and with a 48 hour flow the digestion is not very much more. Some of the deposit indeed is not reducible, and must accumulate.

7252. Then do the tanks sooner or later require emptying?—Yes, but it would be advisable where possible not to empty and clean out septic tanks, obviously because it takes months to get a tank into working order. It is much better, where it can be done, and it can generally be done in small tanks, to remove at intervals some of the deposit through a valve. Only a small quantity at a time could be so removed, but in this way the tank might go on working uninterruptedly. In large tanks the removal of sludge little by little is much more difficult, and it may be best, say once a year, to let off the upper water and then remove the sludge, as is now done from settling tanks, taking care always to leave a certain quantity of sludge in the tank so that septic conditions may proceed at once on the flow being reduced.

7253. Was the sludge from septic tanks very offensive?—We expected it would be, but at Leeds we were not inconvenienced.

7254. Now it would be very interesting and useful to learn the amount of digestion of the deposited solids in the septic tanks. Did you try to estimate this?—Yes; and we came to the conclusion that at Leeds in our No. 1 tank at 24 hour flow there was a digestion of 57 per cent. of the solids left in the tank, which is equivalent to about 40 per cent. of those originally in the sewage.

7255. How did you get at this?—In this way: From analyses of ou raw sewage—we know that in the period under consideration the average of suspended solids in the sewage was 44·4 grains per gallon, and the average in the effluent 13·1 grains—so that for every gallon which passed through the tank during the period, 31·3 grains of suspended solids were left behind. This at 90 per cent. water would represent 313 grains of sludge per gallon. Multiplying this by the number of million gallons which had passed, it appeared that if no sludge had been digested it would more than completely fill the whole tank. The tank was, however, only about half-full of sludge. To get a more careful estimate than by the 90 per cent. estimation, the following plan was adopted. By means of long glass tubes 12 sections of the tank at different parts were taken, in such a way as to get in each tube a correct sample of the thick sludge at the bottom, of the thinner sludge above, and of the column of water above that, there being no scum at the time of experiment. These sections were then mixed together and stirred and a sample taken, and the number of grains per gallon was found to be 5·587 grains per gallon. Multiplying this by the capacity of the tank, viz., 250,000 gallons, the suspended solids in the tank were, I think reliably, found

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to be 199,555lbs. of dry matter. The total flow which had in the period passed through the tank, multiplied by 31·3 grains, which each gallon had, on average, left behind, gave 463,536lbs. as the total dry solids left behind, and this gives the proportion of digested matters as 56·9 per cent. of what had been left in the tank. I may add that a calculation made when this tank was emptied and the sludge then measured confirmed this estimate, but reduced the percentage on suspended solids in the crude sewage. This calculation showed that 58·5 per cent. had been consumed of the suspended solids which had been left in the septic tank, but this represented only 28·3 per cent. of those originally in the sewage. When our No. 3 tank was recently emptied, a calculation was made showing 60 per cent. digestion of the sludge left in the tank, which is equivalent to 28·7 per cent. of the suspended solids in the crude sewage. An estimate in connection with the closed septic tank showed a digestion of 40 per cent. of the solids left in the tank, and 27 per cent. of those originally in the sewage. These three estimations are very close, as to the percentage of the digestion of the solids in the crude sewage, varying only from 27 per cent. to 28·7 per cent., and point to a digestion of under 30 per cent. of the suspended solids in crude sewage by septic tank action. It is probable that the proportion would be somewhat larger with simple domestic sewage. It is necessary to add that if the exit of suspended solids in the effluent—which takes away 20 to 30 per cent. of them could be prevented—the digestion would be larger, for the figures show a digestion of 50 per cent. of the solids left in the tank.

7256. Did you ascertain the nature of the sludge or deposit?—Yes; we made many analyses. Roughly speaking, they showed that the dried sludge of our open septic tanks lost on ignition about 50 per cent., leaving ash about 50 per cent., about one-third of which was ferric oxide, and about half silica. Therefore about one-half of the dried sludge was in a form not further reducible by bacterial action. We also analysed the suspended solids coming off in the septic tank effluent, and found their composition to be similar to that of the deposited sludge, viz., half-organic and half mineral.

7257. Now as to the effluents from your open and closed septic tanks; we understood that at Leeds they were black in colour, and carried at first an average of 8 and later an average of 16 grains suspended solids per gallon. Will you tell us what purification was shown in the effluent, as compared with the sewage going into the tanks?—About 54 per cent. as measured by albuminoid ammonia and by oxygen absorbed. The following is the average of the analyses of our No. 1 open septic tank for the year ending January, 1900:—

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hrs., 80° F.).
Crude Sewage	120·8	44·4	2·15	1·02	9·08
Septic Tank Effluent (No. 1)	77·6	13·1	1·83	·455	4·18
Purification effected	—	70 per cent.	14 per cent.	55 per cent.	53 per cent.

7258. Did severe frost affect the working of the septic tanks?—No. Even in hard frost there appeared to be no appreciable deterioration of effluent. On one occasion the scum was frozen hard enough to bear walking upon, and we had several heavy falls of snow. The temperature of the effluent was always well over freezing point. The scum is useful as a non-conducter to conserve the heat of the sewage in the tank.

7259. Did you find that the scum forming, as it would, a roof to keep off air and light was necessary to the action of the tank?—No. The evolution of gas appeared to be going on quite freely when there was no scum, and no effects were noticeable in the effluent when there was a thick scum as when there was none.

7260. Have you made any experiments upon septic action in stagnant tanks?—We tried several times the effect of stagnation for short periods, varying from a week to a month, and found the septic conditions developed very rapidly. We are trying some laboratory experiments on stagnant conditions, and they are not yet sufficiently advanced to give us any reliable information.

7261. Do you attach much value to septic tanks in connection with sewage treatment?—Yes. They are valuable as equalising the sewage and giving fairly constant conditions to the filtration; and, of course, there is the advantage that the septic action digests some of the suspended solids, though not as much as was expected. Another advantage is that the suspended solids passing to the filter are in a finely divided condition, and less likely to choke the filters. From the engineering point of view there is this advantage in the septic tank that there is no loss of head, the effluent going out at the same level that the sewage comes in. Comparing the septic tank with chemical settlement as a first process, the septic tank has the advantage that the cost of the chemicals is saved, and the sludge production reduced by nearly half, because there is a digestion of part of the suspended solids, and the chemicals used themselves swell the volume of sludge. The drying of septic sludge on land or lagoons will not be free from nuisance, but the nuisance will be of short duration, because the putrefaction is half completed, while in the sludge from chemical settlement the putrefaction has not begun, but must eventually arise. Where cost is not a fatal objection, or where there are facilities for economically disposing of sludge, chemical settlement offers this advantage that the withdrawal of suspended solids can be more thorough than by the septic tank action, and the less suspended solids in an effluent the easier the filtration. As yet no satisfactory means has been found to prevent suspended solids coming out in the septic tank effluent to the extent of from 20 to 35 per cent. of those originally in the sewage.

7262. Do you think that the antecedent anaerobic action of the septic tank facilitates subsequent filtration apart from the reduction in amount and the fine division of the suspended solids?—No. I am disposed to think that the filtration is only assisted in regard to suspended solids. The purification of dissolved impurities by filtration is remarkable, and seems as great and as rapid with crude sewage as with septic effluent. When I come to the experiments in the continuous filtration of crude sewage I shall be able to show the interesting results obtained. I don't think the septic tank a necessity in the case of a sewage like that of Leeds, but in small installations, where the sewage would rapidly reach the filter, before the solids, and especially the fæces had been broken up, the septic tank would seem valuable and almost essential to bring about the disintegration of the gross suspended solids.

7263. If the septic tank treatment were to be adopted for Leeds, can you give us any idea of the area that would be required?—Everything would depend upon whether the storm water dilutions (say to a maximum of six volumes, that is five dilutions) passed into the same tanks as the normal flow. At present I think it would be convenient that they should do so. For Leeds, where it is estimated the dry weather flow in five years will be 20 million gallons, eight acres of septic tanks, three yards deep, would have a capacity of 20 million gallons. To deal with dilutions to six volumes, however, 16 acres of such tanks would be required, and in that case the normal flow would pass through the tanks at the 48-hour rate, and when diluted to two volumes at the 24-hour rate. The first dilution is always as bad, or worse, than the normal flow, and it is not advisable to exceed the 24-hour rate till the sewage is more dilute. For four volumes the rate of flow would be a 12-hour rate, and for six volumes would be at an 8-hour rate, which with such dilute sewage would do no harm, especially as it would not last long. If it were possible to provide this capacity in two large tanks or reservoirs of

eight acres each, the cost would be moderate, but I fear difficulty would arise in connection with removal of the sludge. In such case, too, the wind would cause waves, and probably prevent the formation of scum, except in quiet weather. It is a question whether wind could not be utilised to drive floating scum more or less automatically over a ledge. If it were found that removal from the surface did away with the necessity of removal from below, it would simplify the engineering problem.

7264. (*Chairman, for Sir Michael Foster.*) The irreducible deposit of which you spoke is, I suppose, irreducible because it contains inorganic matter—that is, iron, rendue, etc., etc., either irreducible in itself or rendering a certain quantity of inorganic matter ireducible by entering into some form of combination with it. There is no evidence, is there, that in the septic tank the organic matter *per se* undergoes such a change as to become irreducible?—No, I do not know of any evidence of that kind.

7265-6. If that is so, probably there would not be the same amount of irreducible deposit in a septic tank in case of sewages free from iron?—I think in the case of domestic sewage or even sewages mixed with trade effluents where there was no iron, there would probably be a larger proportion of suspended solids that would be reducible. I think that in those cases there would be a larger proportion of reducible solids than in our case. It would be a very interesting thing if someone would in connection with the suspended solids with domestic sewage, make an analysis. We have no opportunity of doing it; we have no mere domestic sewage, but I should very much like to know if Dr. McGowan would find out for us what is the composition relatively to organic and mineral matter of the suspended solids in domestic sewage. I should expect to find that it would be to a larger extent a reducible than an irreducible proportion.

(*Dr. McGowan.*) We shall have the opportunity of doing that almost immediately in connection with the experiments at Ilford in Essex.

(*Colonel Harding.*) Mr. Frye tells me that he has made analyses at Accrington of the suspended solids in sewage which is largely domestic sewage, and that the proportion of organic to mineral is larger than at Leeds, but not very materially larger.

7267. (*Chairman.*) At Accrington, where there is not so much mineral in the sludge, is there still the same amount of irreducible?—No, I think what Mr. Frye means is that the analyses of the suspended matters do not show that in that sewage the proportion of organic matter is much greater, though it is greater, than at Leeds.

7268. Although it is only a domestic sewage?—Although it is mainly domestic sewage.

7269. That is rather what one would have expected, is it not?—I should have expected that in simple domestic sewage there would be a much larger proportion of organic than mineral matter.

7270. (*Mr. Power.*) Have you formed any definite judgment, when you are dealing with five times the dry weather flow volumes at your works, whether it is an advantage or a disadvantage to pass the whole of that volume through the tanks. Do you think such storm sewage has any deleterious effect on the tanks, and subsequently on your filters. Does it greatly increase the amount of suspended matter. I am thinking of a 24 hour flow tank now?—We have tried a 24 hour flow and quicker on those, and I have stated in my answers that we did not find any material advantage in running slower, and that in running faster the disadvantage was that we brought out more suspended solids than it was wise to pass on to the filters.

7271. You washed them out of the tank, in fact?—No, we did not wash them out of the tank, but the passage through more rapidly prevented them settling.

7272. You do not think you got more of this irreducible matter passing on to your bacteria beds than you would otherwise?—Yes, we did.

7273. You did?—We got much more, but it is fair to remind you that these experiments with the increase of flow were with the same sewage and not dilute sewage. If you were passing through dilute sewage probably that evil would not arise.

7274. This was all with the same strength of sewage?—With the same—the same sewage. We simply increased the flow or reduced the flow, but it was the same sewage. If we had been passing very dilute sewage I am quite sure in that case we could have increased flow considerably for short periods without bringing out from the tank such an amount of suspended solids as would interfere with the action of the filters.

7275. Then the rapid silting up of your first tank when you passed sewage through quickly was largely due to the fact that you were dealing with crude sewage and not with sewage diluted with storm water. Your first tank silted up very rapidly, and rose above the surface?—Do you mean the first septic tank?

7276. The first septic tank?—No, only in one case where we were working tanks in series did that arise. Our first septic tank worked for nearly two years without anything being withdrawn, but I think what you are referring to is to the first of a series of tanks.

7277. Yes?—In which case, of course, the flow would be a very rapid flow. I think a flow of about four times the 24 hours flow, and in that case no doubt the first tank of the series choked up before septic conditions arose.

7278. With a six hour flow of strong sewage in fact?—Yes, the six hour flow was too rapid, and the bed was full of accumulations before septic conditions had fully developed.

7279. It was not a quicker flow than a six hour flow?—I do not think it was. I think a six hour flow is too rapid. It does not give time for septic conditions to arise. As I have stated in one of my answers, a settling tank and a septic tank only differ in regard to the rate of flow. If the rate of flow is a rapid rate, then the matter settled chokes up the tank before septic conditions have time to arise.

7280. You have records of the several amounts of suspended matter in the tank effluent parallel with the changed rates of flow?—Yes, we have, and we have paid special attention to our No. 1 tank. Not No. 1 of the series, but a tank which we know as No. 1 which has been running for a long time—24 hour flow, and we have constant analyses of the suspended solids which have come out of that tank from the beginning.

7281. And the quality of that suspended matter as to inorganic and organic constituents?—Well, we have made analyses which show that they are substantially half and half, but what I was alluding to specially was the volume of the suspended solids coming out, and those show at first when the tank has had its full capacity the suspended solids were less in quantity, and as the tank gradually filled up, and therefore the capacity of the tank became less, and relatively the flow became faster, the quantity of suspended solids coming out increased. We began on our No. 1 with about 8 grains per gallon, and towards the end of the time the average was 16 grains per gallon, and occasionally more than that.

7282. And the proportions of organic and inorganic constituents of the suspended matter remained about the same?—About the same, roughly half and half.

7283. (*Major-General Carey.*) With regard to the rate of flow through the tanks, did you ever make experiments with an intermediate flow of 36 hours?—No; we tried 24, and we tried 48; we did not try the intermediate speed for any length of time. For a short time we got a speed which would be equivalent to that, for a short time. (*Mr. Harrison.*) Yes, four months. (*Colonel Harding.*) But no material alteration would be expected in such a case.

7284. And I understand from the Leeds experiments you attach no importance whatever to the tank being covered over?—No. We obtain practically the same results from the open and closed tanks.

7285. At the same time the cost is increased by covering the tank?—I pointed out that where the tank is covered, of course the wind has no action upon the scum. The conditions perhaps are more constant in the covered septic tank. I do not think the existence or non-existence of the scum affects the action of the tank seriously.

7286. I want to understand the answer to one of the questions put to you by the Chairman. You think arrangements should be made for drawing off the deposit from the septic tank?—Obviously there must be a withdrawal of the accumulation at some time, and if that could be frequently withdrawn in small quantities——

7287. From the bottom of the tank?—From the bottom of the tank I think it would be advisable, and it may not be convenient to do that; if the tanks are of large size it may be more practical to let the tanks

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stand and remove the supernatant liquor, and then empty in the usual way the sludge in the tank, taking care to leave in the tank at least 5 per cent. of the sludge, so as to bring about septic conditions as soon as it is restarted. If the tank is absolutely cleared weeks will be required before septic conditions develop.

7288. But would not a very great nuisance probably be caused by emptying the tank in that way by taking the deposit?—I thought at one time there would be a great deal of trouble in dealing with the septic tank sludge. Our experience has not borne that out. No doubt the septic tank sludge at the time when it is withdrawn may be more offensive than the sludge from ordinary chemical precipitation at that time, but that is because the putrefaction has to some extent proceeded, and I think the nuisance will probably be over within a shorter period, because the putrefaction would be sooner completed; whereas, in the chemical precipitation, with which we are now dealing—well, at the moment of withdrawal, owing to the admixture of lime, there is a keeping back of the putrefaction. The putrefaction must ultimately arise, and, of course, does ultimately arise, and causes very great and very long-continued nuisance in the lagoons, especially in summer. I do not think from what I have seen that the septic tank sludge would offer serious difficulties as compared with the other. Mr. Harrison reminds me it would be easier to deal with septic tank sludge, because it dries more rapidly; it settles and dries more rapidly than the other sludge; it is more largely mineral.

7289. You have not made any experiments to ascertain whether the septic tank effluent could be passed directly over land without nuisance?—We have had no opportunity at Leeds of trying experiments of that kind. It would be interesting. We have had no opportunity as we have had no land.

7290. Or into tidal waters?—We have had no opportunity of testing that.

7291. (*Professor Ramsay.*) Have any experiments been made as regards the amount of digestion in a septic tank?—We have made one estimation that is not in the evidence I have brought before you, but which you may remember I read out just now, in which we showed that the results were practically the same.

7292. At what depth would you consider it necessary to clear out a septic tank, to clear some of the deposit out—down to what depth?—You must be guided by the amount of suspended solids coming out in the effluent; the evidence of accumulation is obvious enough in the suspended solids coming out in the effluent, and when the amount of those suspended solids becomes so large that one thinks it inadvisable to put them upon the filter, then is the time to clear out the septic tank. I do not think it is necessary to gauge any particular depth, say any reduction to half, or anything of that kind; it is better to go by the suspended solids in the effluent.

7293. Are there any means of knowing to what extent the capacity of the septic tank has been reduced?—Yes, from a gauge of it.

7294. I forget whether at Leeds your septic tanks are worked in series or parallel. My recollection of Leeds is that the sewage passes through a series of septic tanks, is that not so?—At Leeds we have three or four tanks working independently, and we have also tanks working in series.

7295. Then has there been any examination of the sludge from both of those?—Yes.

7296. Comparison?—Yes.

7297. With what result?—You mean as to the relative constitution, organic or mineral.

7298. Yes?—Has there been any separate comparison? (*Mr. Harrison.*) Yes, they were taken a year for sewage, they are practically the same. (*Colonel Harding.*) Substantially, the results are the same—about 50 per cent. organic and 50 per cent. mineral; the differences are not great, they differ a few points.

7299. One would have expected a difference in the first series?—Not necessarily, but after storms.

7300. Was the result taken as the result of all the septic tanks in the series?—Yes.

7301. And then is there any knowledge as regards the amount of sludge in these septic tanks? Of course, the first septic tank in the series keeps the sludge up very rigidly?—Yes.

7302. How does that compare with the septic tanks which are run separately?—Independently.

7303. Independently?—The independent one, I suppose, has a much longer life than the first of the series?—Yes, the independent tank has a longer life, but not so long a life of course as the last tanks of the series; those have a very long life, because the bulk of the suspended solids settle in the first of the series.

7304. Then have you made up your mind which plan to adopt?—I cannot say we have, but it does seem as if it would be perhaps more convenient to have tanks in series, because the sludge in the first tank would be denser, and it would be more convenient of removal.

7305. Have you thought of the possibility of altering the order of the tanks in a series, making the second tank the first, the third the second, and so on?—That is a very interesting suggestion; and it has been followed out in connection with chemical and other settlement, but we have not tried it in connection with septic tanks. It is very interesting, because you would get denser sludge when you do empty than you would if you emptied the very thin sludge in the last of the series.

7306. This process of methodical treatment is very common in instances of the same sort from a chemical point of view?—But it has also been applied to chemical precipitation of sewage.

7307. Is it proposed to use the sludge that comes out of the separate tank for gas generating in the way you have described?—No, the matter is really new; I do not know as to the relative value of septic sludge and sludge from chemical precipitation at the present moment. As I was telling you, experiments are going to be made as to the manufacture of briquettes from one sludge, and we should probably try experiments with the other sludge, but as yet we have no evidence as to the relative value of the sludges.

7308. Is there not some difficulty as regards the classification of the solids—in distinguishing what is soluble in sewage; is it not possible that that solid is colloidal?

7309. (*Mr. Harrison.*) Yes, part of that no doubt is colloidal, and passes through your septic tank?—Yes.

7310. Where it really is actually suspended?—Really, yes.

7311. The method of examining that I suppose would be to filter off some through a Pasteur filter?—Yes.

7312. Has that been done?—Yes; I have seen it done.

7313. Have you adopted it?—No, Mr. Frye has done it.

7314. With what result, Mr. Frye?—(*Mr. Frye.*) As regards septic tanks?

7315. As regards septic tanks?—There is colloidal solid in the septic tank; there is less colloidal solid in the tank than in the sewage.

7316. So that a good deal of colloidal solid becomes precipitated in the tank?—Yes.

7317. That has been proved?—Yes.

7318. And is that colloidal solid particularly digestible?—I cannot say, I should say not, because a considerable quantity of it is iron.

7319. Not albumen, but iron?—Yes.

7320. Has it been proved that the septic tank digests and removes fibre?—(*Colonel Harding.*) Fibre goes of course into the septic tank, and it does not appear in the septic effluent, I think you have traced it, have you not, in the septic sludge as still existing as fibre?—(*Mr. Harrison.*) Yes, the destruction is very slow. I believe Mr. Frye has made some experiments on that.

7321. Has it ever appeared in the effluent?—(*Colonel Harding.*) I have never noticed it in the effluent. The effluent contains very finely divided substances. I have never been able to detect fibre as such. I do not know whether Mr. Frye has in the effluent. (*Mr. Frye.*) I have put both cotton wool and lamb's wool in the Leeds septic tanks, and found that nine months afterwards—I left them there a long while—both the cotton wool and the lamb's wool had disappeared.

7322. They had been digested?—(*Colonel Harding.*) In nine months. (*Mr. Frye.*) Yes.

7322*. Is there any difference in the temperature between the closed and the open septic tank?—(*Colonel Harding.*) The differences are very slight. In regard to loss of temperature, the difference is slight; if I remember right the loss of temperature in an open septic tank was under 1½ degrees, and in a closed septic tank the loss of temperature was ·8 of a degree.

The difference was not great, and I do not think the temperatures vary to any important extent.

7323. The temperature is usually between 55 and 60 degrees?—Well, the temperature of Leeds sewage rarely falls below 51, and it rises in summer to 66.

7324. Would there be any advantage in artificially heating septic tanks?—We have tried no experiments in that direction.

7325. Do you think it would be advisable to try it?—Any answer I give would be based upon nothing; at least I would prefer not to give it.

7326. Does the septic tank act differently in summer and in winter?—I think as far as I have been able to judge it does.

7327. I do not think it is an idle question. I think that if it is possible for Whittaker to heat his sewage before it runs on to his filter it should be much easier to heat the contents of a septic tank?—I should think the greater the heat the more rapid the putrefactive changes. Is not that why in the incubator we keep samples at a higher degree of temperature?

7328. But it relates to the area which would be covered by the septic tanks; it might effect a large reduction of area?—It is a point worth consideration.

7329. Would it pay you in Leeds to blow steam into the water?—I think it might be worth trying on a small scale. We have just started an experimental tank, and I think it would be quite practicable to introduce steam in some form to raise the temperature to see if septic action is increased. I should be quite prepared to find the increase of temperature would increase septic action.

7330. I have been seeing experiments in India, and I noticed that at a temperature of 85 to 90 degrees Fahrenheit the process of digestion in septic tanks is very much more rapid?—I should be prepared to find that it is.

7331. You do not find that storm water affects your tanks injuriously?—I have had no opportunity of dealing with our storm water on our tanks. The flow is taken from our main channel, and it is not increased. When the storm water arises we get more dilute sewage, but the volume of it is not greater.

7332. Is not that a subject for experiment in resolving on the ultimate size of your tanks?—Yes, but we have been able to judge that it is easier of course to deal with dilute sewage. You get better effluents with dilute sewage, and I think we might quite safely argue that with dilute sewage you may increase the flow.

7333. The temperature of course of dilute sewage would be lower?—Would be somewhat lower.

7334. Would it not be possible to make a septic tank of eight acres area?—It would be quite possible.

7335. Would it not be impracticable; I mean, would the whole of the sludge not settle there?—It is an engineering point of much interest to me. If we adopt septic tanks for Leeds, I should not like a number of small tanks because that construction would be expensive. If it were possible to have, as I think I rather suggest in one of my answers, an eight-acre septic tank, that might be readily made by simply putting a bank round that area, and I have no doubt whatever that the action would be effective. Probably the wind would prevent the formation of a scum, but it has occurred to me that the wind might be utilised for the purpose of pushing the scum over a ledge as it is formed.

7336. Over the edge?—Over a ledge, and it is just conceivable that the removal of such matters by wind would do away with the necessity of removing anything from the bottom of the tank, but we have not any experience as yet upon that point. I grant, however, that there would be great difficulty in connection with a septic tank of great area in removing the sludge, at least in removing it from time to time through valves. You would only remove it locally. The only way to remove it would be by stopping the action of the septic tank, running off the water, and then pumping out the sludge in the ordinary way, and no doubt the larger the tank the greater the difficulty would be. I am afraid it may prove impracticable to have septic tanks made on so large a scale, but it is an interesting point.

7337. Would the public not be largely repelled by a huge tank which would smell badly?—But I do not think that that really affects the question, because if you do not have the eight acres in one tank you have eight acres of tanks in a series.

7338. They could be covered; you could grow grass on them, and people would not be able to distinguish them from ordinary fields?—A mere sentimental advantage. I do not think it would affect the question of any nuisance that might arise.

7339. You do not think that it is the final condition of a septic tank to be covered over with grass?—It could be quite easily covered over with grass. Where you have a thick scum, seeds will certainly settle. We have had luxuriant local crops on different parts of our scums, but at times these scums disappear.

7340. For no good reason?—For mechanical reasons, due to wind and other conditions.

7341. But even on the small tanks do they disappear?—Yes.

7342. I thought they were permanent in the small tanks?—It is very curious that on our tanks, which are one-eighth of an acre in area, sometimes we have very thick scums, one and two feet thick, and at other times we have none at all.

7343. And does the scum sink?—It disappears; it possibly sinks; it is disturbed by high wind, the gas escapes from it, and it sinks, not all at once but gradually. The existence of the scum seems to be due to mechanical causes, to the effect of the scum drying the surface, and so making such surface impervious, and so the gas supports it, and reasons of that kind.

7344. Have any experiments been made on pressing tank sludge?—Not by us.

7345. Or by anybody else?—Nor do I know of their having been made by any one else. At Accrington, where the chief experiments have been carried out, I think they have simply passed the sludge into lagoons, and let it dry gradually.

7346. But if wished to be used for fuel it would be much more easily dealt with?—I think it would be much more easily dealt with; it could be dealt with more rapidly.

7347. (*Mr. Killick.*) You mentioned the fact that your sewers act as septic tanks?—Septic action takes place in sewers.

7348. They act in a similar way?—Yes.

7349. Therefore in forming an installation for sewage works consideration should be had to the length of the sewers bringing the sewage to the works?—It may be taken properly into account, because undoubtedly septic action does take place where sewage passes through a long length of sewers.

7350. I think you hold the opinion that if sewage is to be treated by artificial filtration to the extent of six times the normal dry weather flow it would be well that the septic tanks hold twice the normal flow?—I think it is desirable.

7351. Desirable?—Yes; on these grounds, that if you have a normal flow of, say, 24 hours, and you increase that by six times, you will bring out more suspended solids, especially in the first rush after a storm, than your filters can deal with.

7352. Then in providing for the treatment of six times the normal flow tanks, providing for 48 hours flow would be sufficient?—I think so.

7353. (*Chairman.*) We may now, I think, pass away from the septic tanks, which we may assume to be a mere first process of sewage treatment, to be necessarily followed by filtration either on land or on artificial filters. Now, have you had any experience of the treatment on land of septic tank effluent?—No. We have no available land at Knostrop for such experiments.

7354. Then will you tell us what trials you made in the artificial filtration of septic tank effluent?—We have made experiments in intermittent or contact filtration. Our experiment in single contact filtration on bed No. 8 has already been referred to, as also those on the single contact beds, in connection with our Cameron installation. We found that the results obtained by single contact filtration were fair, but never reached the Rivers Board's standards, but with double contact filtration we obtained very good results. Our experiments in double contact filtration of septic effluent have, however, not been continued long enough to enable me to speak with confidence as to capacity reduction, though I am satisfied that satisfactory filtrates can be obtained by this system. Our attention in regard to filtration of septic tank effluent has been mainly directed to experiments in continuous filtration, for which I venture to suggest as a better name "trickling" filtration. I mean by that, that the effluent passes on to a bed continuously, but in a very

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slow flow, so that the sewage trickles through the material, and the action is not interrupted.

7355. What was the construction of your first trickling filter?—It was on lines suggested by Mr. Whittaker, of Accrington, who has since considerably extended the application of this system of sewage treatment in his own town. The bed is circular, 45ft. in diameter, 10ft. deep, and not having to stand any pressure of water, is merely surrounded with wood laths kept together by iron bands. Within this light screen the clinker is piled up. The bottom consists of a circular layer of concrete, having an 18in. collecting drain running along one diameter, with a fall of 1 in 45. This drain forms the main carrier into which 9in. pipes run, having a fall of 1 in 22 to the larger pipe. These smaller pipes are also perforated half round with small holes. A manhole rises vertically from the centre of the bed, having a diameter of 6ft. formed of open brickwork. The clinker is between 3in. and 1in., except around the manhole and the extreme circumference, where a layer of very coarse clinker is placed. Effluent obtained from our No. 1 open septic tank was pumped by means of a pulsometer to the Whittaker rotating sprinkler, and by it distributed in a shower over the whole surface. The bed was started on March 9th, 1899, at the rate suggested by Mr. Whittaker, of 600 gallons per square yard—that is, at the rate of 3,000,000 gallons per acre per 24 hours.

7356. And what was the career of this filter?—Well, we soon found we could not long continue to work at that rate. For the first days the filtrate was quite clear, but did not give good analytical results. All suspended solids were at first kept back mechanically by the filter, but little or no bacterial action had arisen. The filtrates improved, however, when the filter had been at work a week, and members of the Commission will perhaps remember that when they visited Knostrop works on March 21, 1899, the filter having been at work 12 days, the filtrate was still quite clear, and was then beginning to give good analytical results. Soon afterwards, however, suspended solids began to work out with the filtrate, and by March 28 the bed showed signs of surface clogging, and a week later pooling extended on the surface so that the effluent began to run down the sides and the central manhole. The analyses then fell off rapidly. The top surface became coloured with iron deposit and a growth developed which prevented the flow of 600 gallons per square yard passing down. The flow was therefore reduced to 200 gallons or one third, and this gave improved filtrates, but the pooling continued, and it became necessary to rest the bed for a few days. On restarting, the results again improved, the nitrates rising to ·77, but again in a few days there was a falling off due to the choking of the upper surface by an abundant gelatinous growth which prevented the effluent passing down and affected the aeration. When the filter had been at work two months the work was stopped and the surface dug down. It appeared that the growth was on the surface and did not go down many inches. The surface was therefore removed to the depth of a foot, and on restarting the filtrate was again good, but fell off rapidly as the new surface became choked.

7357. Was not the effluent as put upon the bed artificially heated?—Yes, it was; and that I believe was the cause of the excessive development of the surface fungoid growth. Mr. Whittaker desired us to use a pulsometer for raising the effluent, and as the waste steam of the pulsometer condenses into the effluent pumped, the effect is to heat the effluent, but in addition to this Mr. Whittaker had arranged to inject a jet of steam into it. We found that the temperature was being raised 10° Fahrenheit, and as in any case it would be too costly to do this on a large scale we at once decided to stop the injection of steam; but the pulsometer alone was found to raise the temperature of the effluent several degrees. I should add that Mr. Whittaker attributed the bad result of this filter to our having used clinker too small, viz., from 3in. to 1in.

7358. Was the experiment then abandoned?—No. We again removed the top surface to a depth of a few inches, and covered it with very coarse material, 3in. and above, for a depth of about 12in., in the belief that as the fungoid growth did not go far down this coarser material would prevent the surface clogging and pooling. This was done on July 10th, 1899. A great improvement in the quality of the filtrates was produced, as shown by the increase of nitrates, which on July 13th were ·756. The filtrate continued to be clear to July 30th, but from the latter date large quantities of brown suspended matters came out from the bed, causing the values obtained from the Alb. NH_3 and oxygen absorbed tests to rise considerably. The free NH_3, however, remained very low (about ·2), whilst the N as nitrates remained over ·7 grains per gallon, showing that the aeration of the bed was not being interfered with. The coming through of these solids in suspension in the filtrate was at first very disappointing, and was looked upon as condemning the system. Further experience, however, has shown that a large part of these solids are irreducible, and, therefore, if they do not come out, but stay behind in the filter, they must necessarily choke it up. They were soon found to be non-putrescible, and to be readily settled. In these conditions and working at the rate of 250 gallons per square yard, the experiment went on for three months before the pooling of the surface arose, and it became necessary to fork over. Whenever this was done there was an immediate improvement in the filtrate, and it became evident that to obtain good filtrates it was absolutely necessary to keep the surface open.

7359. But in this filter the sides or circumference were quite open to the air, were they not?—That was so, for the coke was only held together by laths of wood placed 3in. apart, but from our experience side aeration seems to be of very little value, as our further experiments will show.

7360. Give us some idea of the purification effected by this process?—I put in the following table:—

AVERAGE OF ANALYSES referring to Period from 9th March 1899 to 8th May 1900 (14 months).

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours., 80° F.).	Nitrogen as Nitrates.
Septic Tank Effluents	78·4	13·1	1·80	·434	4·02	—
Filtrate—Whittaker Bed, No. 1	69·8	5·6	·688*	·113*	·684*	·548*
Purification effected on Septic Effluent	—	57 per cent.	61 per cent.	73 per cent.	83 per cent	—

* Analysis made after rough settlement of suspended solids.

The following Table is the Average of a Number of Comparative Analyses made upon the Filtrate from the Whittaker Bed, No. 1, with and without Suspended Solids:—

Grains per Gallon.	Albuminoid Ammonia.	Oxygen Absorbed.
Filtrate containing Solids	·233	1·40
,, after Settlement of Solids	·105	·610

I should add that after a year's working, in April, 1900, the filtrate greatly deteriorated, the suspended solids which had been brown became darker coloured, and the supernatent liquid obtained after settling them was opalescent, and threw down buff-coloured iron precipitate similar to that from the contact bed filtrates of which I spoke earlier in my evidence. The liquid began to run out at the sides of the filter, and this time it did not appear to be due so much to the surface growth, which since coarse coke had been put on the surface had not troubled us very much, especially after the injection of steam had been stopped; but the choking now appeared to be in the interior of the bed, for forking the surface did not improve matters. We concluded that while a

certain portion of the irreducible suspended solids came out in the filtrate, they did not all come out, and that the choking was now due, after a year's working, to accumulation of undigested, and, indeed, indigestible, matter. The bed was then given a long rest of several months. In view of the fact of the suspended solids being non-putrescent in character, the following analysis may be of interest. The sludge produced by the settlement of the filtrate was washed, and as far as possible freed from the larger living organisms, such as worms, larvæ:—

Loss on ignition - - - - -	= 31·3	per cent.
Ferric oxide - - - - - -	= 31·3	,,
Silica and matter insoluble in acid	= 18·9	,,
Other mineral matter - - - -	= 18·5	,,
	100·0	,,

7361. What conclusion did you come to as the result of this experiment?—This experiment was a very useful and suggestive one, but showed that with the effluent from the Leeds septic tanks, which contained an average of 13 grains per gallons of suspended solids, the bed had been constructed of material too fine, and we therefore resolved to construct another bed of much coarser material and make further trial of the system.

7362. Tell us now about your coarser Whittaker bed?—The construction of this No. 2 bed was as follows:—Rows of semi-circular perforated tiles, having a diameter of 18 inches, were placed edge-to-edge, and raised above a slight inclined plane of concrete by means of small brick columns, so that there was a clear air space between the tiles and the concrete floor. Upon this floor was built an octagonal pigeon-holed wall, and the space within the wall was filled in with coarse coke to a depth of one foot above the pipes, and the rest of the bed with coke of not less than 1½ inches diameter. Altogether the depth of coke was 9ft. The septic tank effluent was distributed over the surface by a Whittaker sprinkler. The rate of filtration was 1,000,000 gallons per acre (*i.e.*, 200 gallons per square yard) per 24 hours, working night and day. The bed was started on September 2nd, 1899. The first filtrates obtained were exceedingly clear but putrescent, showing that though solids in suspension were being kept back, bacterial action was not yet developed. This continued until September 19th, when the filtrate became turbid from suspended solids coming out; but, nevertheless, nitrates were present, and the filtrates were non-putrescent in character. Since then the filtrates have remained turbid but non-putrescent, and no change has been made to the bed itself until April 7th, 1900, when some of the coke upon the surface, which had become broken (partly by walking upon it to attend to the sprinkler), was renewed. Work was continued night and day at the same rate of 200 gallons per square yard, until May, 1900, that is for about eight months, when the filtrates began to deteriorate, although there was little pooling on the surface. This we considered to be due to the fact that at the 200 gallon rate, that is one million gallons per acre, the flow only brought out a part of the indigestible solid matters with the filtrate. The remainder accumulated, and in time interfered with effective aeration.

7363. When a continuous filter becomes so far choked that it is no longer efficient, can anything be done to clear it?—That is, of course, a very important point. We had noticed in this filter, and also in our earlier Whittaker bed, that if, for any purpose, the arms of the sprinkler were held from rotating, then within a few minutes the filtrate became very turbid, with an excess of solid matter coming out. This was due to sending the whole volume, which during the rotation of the arms is distributed over the whole surface through only a small part of it, and so increasing tenfold the flow through that part. This suggested that with a coarse bed like this No. 2, the bed could be washed out; accordingly a three-inch hose, with town's water, was turned on one square yard of the bed, and successively over the whole surface. The bulk of the accumulated solids came out in the first three minutes, during which the filtrate was exceedingly turbid; a test tube with ten inches in it settling down three inches of sludge. After the first few minutes the volume of solids coming through rapidly diminished. With these washed-out solids came out an immense number of cyclops, larvæ, etc. The sludge was found only slightly putrescent, although it would necessarily contain organic matter in process of transition. No doubt, if the experiment had been made after a rest of one or two days, the sludge would have been as little putrescent as that which comes out in the normal flow. The filtrates obtained immediately after the washing out were not good, and it took about a fortnight to bring them to the old standard, and indeed they then so far improved that the nitrates rose to 1·31 grains per gallon. No doubt in this suggestive experiment the washing out had been too thorough, and some bacterial life had been cleared out with the accumulations.

7364. Do you suggest then that practically such beds may be washed out by turning a hose upon the surface?—Oh, no! that would, of course, be too costly. The washing out of accumulations would take place by increasing the flow, say, from 200 gallons, if that is the normal rate, to 400, 600, or 1,200 gallons per square yard. Such increased flow would arise automatically with rainfall and dilution of the sewage, so that after storms the filters would recover their full efficiency. This is an important feature.

7365. At these greater rates of flow the purification would be less?—No doubt; but then after the first rush of a storm the diluted sewage is very weak, and there is less purification required.

7366-7. But these accumulations of suspended solids, which would at such times be washed out, increasing the turbidity of the filtrate, should not be allowed to go to the stream?—I think that in trickling filtration over coarse material, where suspended solids come out always in the filtrate, and accumulations are at times washed out, it will probably be necessary to have a settling tank at the end of the process, unless the filtrate can be passed over land. It is well to note that these washed-out solids are at Leeds non-putrescent. I understand that they are putrescible in the Accrington filtrate, the difference being probably due to the large quantity of iron in Leeds sewage.

7368. Your answer to a previous question suggests that its presence is not altogether objectionable?—That is so. At one time when we were experimenting with contact beds, we thought the iron in the sewage a great trouble, partly because it took up oxygen which was required for the organic matter, and partly because it deposited in the contact beds, and helped to sludge them up. Now, in coarse trickling filtration the iron which reaches the beds in solution nearly all comes out into suspension; but as it comes through, the only objection is that it adds to the mineral matter to be afterwards settled out.

7369. Have you any analyses of the filtrates of your No. 2 Whittaker bed?—Yes. We made constant analyses, and I put in a table based on 111 analyses:

AVERAGE OF ANALYSES referring to Period from 2nd September 1899, to 30th June 1900 (10 months).

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° F.).	Nitrogen as Nitrates.
Septic Tank Effluent - - - -	78·1	14·4	1·85	·455	4·18	—
Filtrate—Whittaker's Bed, No. 2 - -	70·7	7·7	·532*	·079*	·590*	·669*
Percentage Purification on the Septic Effluent.	—	46 per cent.	71 per cent.	82 per cent.	85 per cent.	—

* Analysed after the rough settlement of suspended solids taken from October 23rd, 1899, to June 30th, 1900.

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The following Table is the Average of a Number of Comparative Analyses made upon the Filtrate from Whittaker Bed, No. 2, with and without Suspended Solids:—

Grains per Gallon.	Albuminoid NH_3.	Oxygen Absorbed.
Filtrate, containing Solids - -	·183	1·27
,, after Settlement of Solids	·069	·522

7370. Have you anything further to tell us about experiments in trickling filtration?—Yes. Besides these experiments with septic tank effluent, we have made several experiments with more or less crude sewage.

7371. In what form?—With a Ducat filter, with a series of triplicate beds, and with a bed which, to distinguish it, we call a "Leeds bed."

7372. Tell us first about the Ducat filter?—Col. Ducat suggested that sewage could be dealt with on his filter without any antecedent treatment, and we constructed a bed on plans provided by him and under his supervision. Although the construction is prohibitively costly, we hoped that if it gave good and lasting results with Leeds sewage, some simpler form of it might later on be devised. Our Ducat filter has an area of 1-100th of an acre, 48·4 square yards, and a depth of 10ft., the material used being clinker three-eighths inch to five-eighths inch. The sides of the bed are built, not of brick, but of drain pipes, 12 inches long and 5¼ inches external diameter. This construction secures the complete exposure of the sides of the filter to the air. Outside this perforated wall is a second wall, distant from it about three feet, and built of solid brickwork for the purpose of keeping in the heat, and it carries a roof covered with thatch. The bottom of the bed has six perforated brick channels connected with the outer air, through which pass cast-iron hot-water pipes connected with an external boiler, intended to supply artificial heat during cold weather. The crude sewage was raised to the level of the bed by means of a Tangye pump, and passed through a three-sixteenths inch screen and a small grit chamber. The distribution of the sewage was by means of tipping troughs. The bed was started on March 29th, 1900, working alternate hours for ten hours, and resting for fourteen, the rate of flow while working being 200 gallons per square yard. The filtrate on April 6th was exceedingly clear and bright, suspended solids being retained in the bed. On April 14th the bed was worked for 10 hours continuously, with 14 hours' rest. This change immediately caused the filtrate to become opalescent, but after a day's working it again cleared. On April 16th the surface showed signs of choking, and small pools began to form. On April 26th the whole surface was practically covered with stagnant sewage; the filtrate steadily deteriorated, and at the same time a grey filamentous growth began to appear in one outlet basin, very similar in character to that found on the surface of the Whittaker beds. The unsatisfactory character of the effluent led on April 27th to reducing the work to alternate hours work for 10 hours, with 14 hours' complete rest. The change produced no alteration for the better, and on April 30th, 1900, the process was temporarily stopped. It was found that with the fine material used by Col. Ducat in this bed practically all of the suspended matters had been arrested upon the surface, and, by preventing the efficient aeration of the filter, had produced the bad filtrates. During the whole of this period the bed was warmed by means of the hot-water apparatus, the temperature of the filtrate being about 10° F. higher than that of the sewage. The filter, when giving the best results, produced a purification of 90 per cent. in albuminoid ammonia, and 93 per cent. in oxygen absorbed upon the sewage sent on to the bed. The nitrogen present as nitrates in the filtrates also reached ·56 grains per gallon.

AVERAGE OF ANALYSES referring to Period from March 29th to April 30th, 1900.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed, (4 hrs., 80° F.).	Nitrogen as Nitrates.
Sewage - - - - - - - -	129·7 71·6	53·7	2·88	1·09	7·98	—
Filtrate - - - - - - - -		Nil	1·00	·122	·711	·313
Percentage Purification - - - - -	—	—	65 %	88 %	91 %	—

It was thought that the chief cause of the clogging was due to wool fibre passing the screen and so getting on to the bed. To obviate this, the sewage, before going on to the bed, was now sent through a three-sixteenth inch screen, and then through a layer of the bed material one inch in thickness. Before restarting, the choked surface was removed to a depth of two inches and replaced by new material. The bed was restarted on June 13th, 1900, filtering at the rate of 200 gallons per square yard for alternate hours for 10 hours, followed by 14 hours' rest. The filtrate at first was opalescent, but this totally disappeared by June 15th, leaving the filtrate exceedingly clear and bright. On June 20th the bed began to work continuously for 10, and rest 14 hours. The filtrate remained clear until June 24th, when the filter was put to work continuously throughout the 24 hours. The filtrate remained very bright and clear. Green growth also began to appear in the basin. During this period the hot water pipes were not used. The temperature of the filtrate was on the average about 4° F. lower than that of the sewage. The best results obtained were as follows:—

AVERAGE of ANALYSES referring to Period from June 13th to July 7th 1900.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed (4 hours, 80° Fahr.).	Nitrogen as Nitrates.
Sewage - - - - - - - -	127·9	59·4	2·79	1·07	9·90	—
Filtrate - - - - - - - -	69·0	Tr.	·165	·043	·241	·848
Percentage Purification - - - - -	—	100%	94%	96%	97%	—

These results, however, could not be maintained. After less than a month's work they began to deteriorate, and when the surface again became choked with the suspended matter the filtrate was so bad that the experiment was stopped. Once more the surface accumulations were removed together with 2in. depth of the clinker, which was replaced by new material. After a fortnight's rest the experiment was renewed with the same results. It is noteworthy that, as in the Whittaker beds, the side aeration seemed to be quite valueless, for when the upper surface was choked the result became very bad. I have come to the conclusion that however it is screened, it is impracticable to deal with Leeds crude sewage on a filter of such fine material.

7373. Then did you succeed any better in trying to deal with Leeds crude sewage on your triplicate and Leeds bed?—Yes, because we used very coarse material,

which allowed suspended solids to come through, but when they came through they were in a changed form and reduced in quantity.

7374. What were these triplicate beds, and when did you start that experiment?—In September, 1899. Three small experimental beds were used, which had been constructed for use as triple contact beds, but had not been put to work for that purpose. These beds were a little over 12 feet square, and had an area of 17 square yards, and a depth of four feet. The first of these was filled with the coarsest coke available, the second with coke to about 1 inch and 1½ inches in size, and the third with small coke about five-eighths inch. The distribution was by tipping troughs, and the sewage used was the crude sewage after passage through three screens, the smallest of which was 37 per inch. The first of these screens, which had one-eighth inch mesh, kept back small pieces of paper, matches, etc.. and the second and third screens kept back most of the fibre, but all the finely divided solids in suspension passed on to the beds. The keeping back of matter by the screens, although it greatly facilitated the work, did not remove any important proportion of the solids in suspension, the matters removed being those which usually do not come into the analysis; as paper, matches, fibre, etc. There was no side aeration at all in these beds. The first filtrates from the fine bed were very clear, the suspended matter being at first entirely kept back by the coke, but after a few weeks these solids began to work through, and the filtrate became somewhat turbid, though giving fair analytical results when the solids had been settled. Trouble, however, arose in two directions, first by the development of a growth in the upper part of the coarse bed, and secondly by the pooling of the sewage on the surface of the third or fine bed. It was soon found impracticable to go on dealing with crude sewage over fine coke, even after passing over two beds filled with coarse coke. These experiments, begun in September, 1899, were stopped in March, 1900; the material was taken out of No. 2 and 3 beds, which were then refilled with very coarse coke, 1½ inch and upwards. When this was done semi-circular perforated drain pipes, nine inches in diameter, were placed in the bottom of each bed, thus reducing the coke depth in each case, but securing more effective aeration. For the tipping troughs on No. 1 bed a Candy sprinkler was substituted. This sprinkler has two arms and works intermittently, sewage passing for one minute, followed by three minutes' rest. This intermittence, in sprinkling was in some respects a disadvantage in connection with such coarse material, for the sewage passed through the beds in rushes. On the other hand the intermittence probably proved useful in improving the aeration of the first bed. This second experiment was started on March 26th, 1900, at a rate of flow of 750,000 gallons per acre, that is 150 gallons per square yard per day. It will be understood, therefore, that this continuous filtration was over three beds of the coarsest coke; the first three feet six inches, and the second and third about two feet six inches each in depth; and no doubt it would have been much better to have had this eight feet six inches of coke all in one column, with a single distributor. The sewage took only a quarter of an hour to pass through the three beds, and the first results were very unsatisfactory with a total purification of about 50 per cent. only. The filtrates gradually improved until in about three weeks the bed had got into condition, but shortly after this, solids began to work through, and made the filtrates turbid. This was the same result which had been noticed on the Whittaker beds; that the solids in suspension were at first kept back, but gradually worked their way down through the filter until they began to come out with the effluent. These solids were found, however, on coming out, to be different in character to what they were on going in. They settled more readily, and were very slightly putrescible. The following table gives the average of the analyses since the starting of the experiment, and including the early bad filtrates. It will be seen that these analyses, although including the solids in suspension, show a purification of 71 per cent. on the crude sewage measured by the Alb. NH_3, and 78 per cent. measured by the oxygen absorbed, but recent analyses made from the settled filtrate show a purification of 90 per cent. as measured by the Alb. NH_3, and 92 per cent. as measured by oxygen absorbed, and nitrates ·3. This result was remarkable in view of the short time taken to pass over the coarse coke:—

AVERAGE of ANALYSES referring to period from March 26th to June 30th, 1900. Analyses are inclusive of all Suspended Solids.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.
Sewage	123·2	44·2	2·36	1·04	8·90	—
Filtrate from 1st Bed	87·6	19·2	1·58	·599	4·37	—
,, 2nd ,,	74·0	7·9	1·15	·430	2·78	—
,, 3rd ,,	71·7	7·7	·828	·297	1·93	·141
Percentage Purification	—	82%	64%	71%	78%	—

7375. You have at times much dye water in your sewage; how was this affected by your trickling filtration?—At times the sewage coming to these beds was deeply coloured with dye, and we were surprised to find that the colour completely disappeared in the final filtrate. Indeed the greater part of it had gone from the first bed filtrate.

7376. Did you vary these experiments further?—Yes; in July, 1900, we tried these triplicate beds for a week as contact beds, with three fillings a day and two hours' contact. This was triple contact filtration through very coarse material. The following was the analysis obtained at the end of the week:—

ANALYSES OF SEWAGE AND EFFLUENTS from the Triplicate Filter used as contact beds.

	Screened Sewage.	Bed No. 1.	Bed No. 2.	Bed No. 3.
Free NH_3	2·02	1·27	1·17	·902
Alb. NH_3	·774	·375	·262	·155
O absorbed	6·57	2·40	1·55	1·19
N as Nitrates	–	–	–	Trace.

In trickling filtration the liquid passes through in a few minutes. The longer contact when used as intermittent filters gave rather better results in alb. ammonia and oxygen absorbed, but there was only a trace of nitrification.

COMPARATIVE ANALYSES OF FILTRATES from contact and continuous filtration.

Grains per gallons.	Free NH_3.	Alb. NH_3.	O absorbed.	N as Nitrates.
Filtrate continuous	·306	·168	1·84	·462
,, contact	·866	·155	1·19	Trace.

As this experiment only lasted a week, I do not lay much stress upon it. One point, however, I want to note, and that is how in contact filtration the material tends to reduce capacity by consolidation. These triplicate filters have been used for nine months for trickling filtration without movement of the material. During the one week of their use as contact beds the filling and emptying had the effect of lifting the coke and then settling it, so that in places the surface sank as much as one foot.

7377. You did not continue this experiment?—No,

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this consolidation emphasising as it did our experience of contact beds in regard to loss of capacity, we restarted the triplicates as trickling beds, and with similar results to those given in my former table. They were worked for four months more without developing any material new feature.

7378. You told us that this triplicate arrangement was accidental, that you saw no advantage in the triplication, and that you proposed to try an experiment with the coke all in one column with one distributor?—Yes, the triplicate arrangement was objectionable on account of the necessity for three separate distributors and the cooling of the sewage which took place in consequence. Indeed, during the winter of 1899 in cold weather the results fell off very much. Accordingly, in November, 1900, we stopped the triplicate experiment, and built a filter with the coke in one column, which we call the Leeds filter.

7379. What was the construction of this Leeds filter?—We left our third triplicate unaltered; we raised its walls with solid brickwork so that it might hold a depth of 10ft. of coke in all, and to fill up to this depth we just removed the coarse material from beds Nos. 1 and 2. So that in the Leeds bed we used just the same material we were using in the triplicates except that a little additional material was required to complete the 10ft. The walls were solid. There was no side aeration whatever. The No. 3 triplicate, which now became the lower part of the Leeds filter, had at the bottom semi-circular perforated pipes, 9in. diameter, and therefore an air space, but air could only reach it through the 6in. opening of the outlet valve which remained wide open. At the old surface level of the No. 3 triplicate we laid a + of perforated pipes, and again another 3ft. higher. Communicating with these, half bricks were left out in the walls, and then loosely put in, so that they could be taken out to obtain samples at different depths of the filter. They have not, in fact, been taken out, so that the aeration is limited to the 6in. opening in the bottom outlet valve.

7380. Were you then working on the supposition that aeration is to be avoided?—Oh, no. I quite think that the aeration of the bottom of a trickling filter should be very complete, but we were anxious to try a filter without side aeration at all, for experimental purposes; and we wanted to be able, again for experimental purposes, to regulate the bottom aeration. We were able, for instance, by burning tow in the mouth of the outlet valve to note that there was there an inward current, and that it passed upward through the filter—as, indeed, one would expect in a chamber closed at the sides, and with sewage warmer than the atmosphere.

7381. Now how did the filter work with the coke all in one column as compared with the same material in the triplicate arrangement?—The results were an improvement in the filtrate and better nitrification, due in my opinion to more perfect distribution and to the heat of the sewage being better conserved. There was also, of course, an extra foot of depth of coke. I should add we used the same Candy sprinkler as before.

7382. When did you start this experiment, and what sewage did you use?—The Leeds bed was started on December 7, 1900, at a rate of 200 gallons per square yard per 24 hours, which on January 21, 1901, was increased to 400 gallons per square yard. I should say that the filter is rectangular, a little over 4 yards square, while the action of the sprinkler is circular, 4 yards diameter. We have not disturbed the bed or dug down to ascertain how soon this circular distribution spreads over the corners, but we have assumed that it does so spread to be complete at half depth, and therefore in the calculation we have taken the area at half way between 4 yards round and 4 yards square, and the 400 gallons per square yard is based on this area—14·04 square yards. The sewage we used was exactly the same screened crude sewage as had been put on the triplicates. It contained an average of about 39 grains per gallon of suspended solids. The paper, matches, tea leaves, fibre screened off do not usually come into analysis, so that the sewage was in effect crude sewage containing all the finely divided suspended solids.

7383. Were you able to gauge how long it took for the sewage to pass through this 10ft. of coke in your Leeds filter?—Yes. We made careful tests to ascertain this. We poured a pint of strong coloured dye upon the surface of the coke, just as the Candy sprinkler (which you will remember is intermittent in its action) was starting, and we found to our surprise that the colour began to appear in the filtrate after 3 minutes, while there was the maximum of coloration within 4 minutes; so that the liquid takes about three minutes in passing through the filter. This experiment was several times repeated with the same result. We also tried our No. 2, or coarse Whittaker bed, in the same way, and found the colour to come through in 2¼ minutes, with full coloration in 3½ minutes. I myself repeated a similar experiment on Mr. Stoddard's filter at Bristol, which has 6ft. depth of coarse clinker, and there found the colour to appear in the filtrate at the end of two minutes, with full coloration in three minutes. In the Ducat bed at Leeds, the material of which is fine, the time of passage was found to be 15min. When one considers the results obtained in this rapid transit by trickling filtration, they cannot but strike anyone as very interesting and remarkable.

7384. But could the transformation of suspended solids take place in so short a time?—No. The liquid runs through the filter very fast, but it would seem that the suspended solids take a very much longer time. It is much more difficult to find out what time they do take to pass through, but judging from the time which passes in a new filter before solids begin to come out in the filtrate, I should conclude that in a depth of 9ft. or 10ft. of coarse material the suspended solids would take 10 days to a fortnight to work through, and during that time they are exposed not only to bacterial action, but to the digestive processes of large numbers of higher organisms. There are the thousands of white flies (Psychoda) which one finds on the coke for several inches below the surface, and the larvæ, worms, and cyclops which are washed out in the filtrate when the flow is increased. The process of purification both of dissolved and suspended impurities would seem to be influenced also by the fungoid growths, which develop on the surface of the beds. The bacterial or oxidising action of the trickling filters upon dissolved impurities would seem to be extraordinarily rapid and effective, since within a three minutes' passage there is accomplished a purification of from 80 to 90 per cent.

7385. That brings me to ask you for the analytical results you obtained with this filter?—You will remember that it was started December 7, 1900. Here is the average of the first six weekly analyses from December 13, 1900, to January 14, 1901, and these are inclusive of the suspended solids. These analyses refer to the period when the flow was at the rate of 200 gallons per square yard, or one million per acre.

Grains per Gallon.	Total Solids.	Suspended Solids.	Free. NH_3.	Alb. NH_3.	Oxygen Absorbed.	Nitrogen as Nitrates.
Sewage sent on to the Bed	103	34	2·	·8	7·86	—
Filtrate	68·5	5·7	·272	·107	·85	·434
Purification	—	—	86%	86%	89%	—

7386. Give us now the results when the flow was increased to 400 gallons per square yard?—I will just give the averages now. In the sewage dealt with the free ammonia was 1·82, and albuminoid ammonia ·76, and oxygen absorbed 7·85. It will be seen that the sewage was somewhat weak, because at the time of this experiment there had been rain and the sewage was dilute. The results of the Leeds bed filtrate at 400 gallons per square yard were these: Free ammonia ·598; albuminoid ammonia ·106 (very very slightly above the standard); oxygen absorbed ·741, distinctly under the standard; nitrogen as nitrates ·193. Those are averages. The nitrates had risen to 2·94 in one case, and it was considerably lower in others. The effect of the filtration at 400 gallons had been to somewhat reduce the excellence of the results, not very materially,

except that it reduced the proportion of nitrates. Those results are inclusive of the suspended solids. The following table shows the difference in the analyses, both inclusive and exclusive of these suspended solids, which it is intended to settle out of the effluent before it goes into a stream. Here are two analyses on January 30th and February 6th. Inclusive of the solids the analysis is, free ammonia ·492; that is reduced when the solids have been settled to ·453; albuminoid ammonia with the solids ·098, without the solids ·068; considerably within the standard. Oxygen absorbed ·769 with the solids, without the solids ·511; nitrogen as nitrates without the solids ·189. Briefly, the results with 400 gallons are very fair, but I am disposed to think that 200 gallons per square yard is a sufficient rate for a normal flow over such a bed, and I should like to add this, that working at 400 gallons we are beginning to be troubled with the excess of growth of the Pylobelus on the surface of the bed. This is a growth which develops most extraordinarily on the surface of the beds. We had at one time a great deal of trouble with it on the Whittaker bed, when we worked at a large rate per square yard. It exists always of course on the Leeds bed, but working at 200 gallons it did not choke the surface; working at 400 gallons we find that the growth of the Pylobelus is excessive, and is tending to pool the sewage on the surface of the bed. I have formed the opinion, therefore, that it would not be wise to work continuously at the 400 gallon rate, but that it would be quite practicable to work continuously at the 200 gallon rate, and that it would be practicable to work for a short time at the 400 gallon rate, and I should think at a much higher rate with dilute sewages.

7387. You said the outcoming suspended solids were not putrescible. Have you made any analysis of them?—The analyses of the suspended solids in the Leeds bed showed loss on ignition of 55 per cent., and mineral matter 45 per cent.

7388. (*Chairman, for Sir Michael Foster.*) You have answered how much is organic, and there is an appreciable quantity. Can you say how far the non-putrescible character of which you speak is due to combination with or the presence of some iron compound, and is it not possible that this non-putrescible constituent in the effluent must in its future course of discharge into the stream or otherwise by some disturbance of the stream become putrescible?—(*Mr. Harrison.*) There is no doubt that the sludge contains a large amount of iron, probably between 20 and 30 per cent. It does not seem to be in combination to any appreciable extent with the organic matter, but it appears to exist there in the form of oxidised iron compounds. These, of course, are fairly stable compounds, and will probably not be going into solution or disappear from the sludge when the sludge settles down in a stream, so that there is very little chance of the sludge becoming putrescent through that cause.

7389. I am not quite sure that I quite understand your answer. You do not think the organic and the inorganic in the sludge are in combination?—No; not to any appreciable extent. No doubt a small portion of the iron is united with some of the organic matter, but the greater part of it consists of oxidised iron compounds totally separate to the organic matter.

7390. And then you do not think that it is possible that the suspended solids which are not putrescible would ever become so?—I do not think so.

7391. Perhaps we might have Mr. Frye's opinion on the same point?—(*Mr. Frye.*) I agree with Mr. Harrison that a great deal of it is pure mixture in chemical combination. I think there is some combination between the iron and organic matter, but I think it is very unlikely that they will separate if they are only mixed in the stream, because they are such a flocculent precipitate, the whole thing. I think if the iron fell that it would take down the organic matter with it. The two adhering to one another so closely that the iron would carry the other down with it, and they would still remain intimately mixed at the bottom of the river.

7392. In this Leeds bed experiment you had, I think, no artificial heating of the sewage, by using a pulsometer or otherwise? How was the work affected by the recent severe weather?—(*Colonel Harding.*) The filtrates deteriorated considerably in the severe weather, and the suspended solids which ordinarily are non-putrescent, during the severe weather are putrescent. The filtrate, including the suspended solids, was not putrescent, but the solids themselves settled out were putrescent, and the filtrate after the settlement of the suspended solids was non-putrescent even in the frosty weather, but the results fell off considerably. I think it is inevitable to conclude that in the absence of any roof, in the absence of any artificial heating, there would be a distinct falling off in the results during severe frosty weather.

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7393. Do you propose to continue or vary this experiment?—Yes. It seems very advisable to continue and to extend our experiments in trickling filtration. We are going to try the Leeds bed with various distributors, and, if possible with a greater depth of coke. It may not be practicable in most cases on account of levels to have a great depth of coke, and, of course, the greater depth would add to the cost; but it would be very interesting, in order to get information, to be able to try passing crude Leeds sewage (screened) through, say, 20ft. of coke. I should expect then to attain a very high degree of purification, after the non-putrescible suspended solids coming out in the filtrate had been settled. Of course, where land is available, it is probable that some 8 feet of coke would be sufficient, and passage of the filtrate through a small depth of soil would leave behind the suspended solids, and complete the purification. Fortunately the City of Leeds has recently been able to acquire a large area of land for sewage treatment, and if the necessary powers are obtained for the scheme it will be possible then to so pass the filtrate over land.

7394. Will you give us your opinion, so far as your experience goes, as to the relative merits of contact and trickling filtration—that is, of intermittent and continuous filtration?—The experience of another six months will be very useful, but after following contact filtration for nearly three years, and trickling filtration for nearly two years, I think that with an equal depth of coke very similar analytical results may be obtained by either system so far as the albuminoid ammonia and the oxygen absorbed tests are concerned, but the filtrates from trickling filtration will contain more nitrates and more dissolved oxygen, and therefore they will to a greater degree have within themselves a capacity of further improvement. But another very important point is this; our experiments show that in trickling filtration the material of the filter is less disturbed, and the life of the filter is very much greater. So far as I am able to judge, trickling filtration over coarse material may be continued for many years without need of renewal of the material, and indigestible solids will pass out naturally, and not choke up the filters as they do in the case of contact beds.

7395. If contact beds were constructed of equally coarse material, could not the solids be washed out just as in coarse trickling filtration?—I think not. The suspended solids in course of transformation seem to take a different form in the two systems. In contact filtration, whether owing to the long quiescent contact or otherwise, they adhere more closely to the material, and take a spongy and flocculent form, while in trickling filtration, where they are continuously exposed to air and to movement, they seem to become more granular and less adherent.

7396. Now, how do you compare dealing with crude sewage direct on a trickling filter, as for instance on your Leeds bed, with that system which consists of a septic tank followed by trickling filtration over coarse material, as in the Whittaker beds?—Our experience of the Leeds bed, that is of treating crude sewage (screened) direct over coarse trickling filters, is too short to enable me to answer this question with sufficient confidence, and in this case engineering questions—questions of cost and levels—come in largely. I think it is practicable to devise automatic screening to remove from the sewage the grosser suspended solids and fibre, which are but very slowly reduced in a filter. Given the satisfactory removal of these matters (which are readily combustible or otherwise dealt with, for they are not in the form of sludge), I think it is quite practicable to deal with Leeds sewage on trickling filters without antecedent septic treatment; and I think that possibly there will on this system be a greater digestion of the suspended solids. Another advantage would appear to be the absence of nuisance in consequence of limiting the treatment to aerobic action. As fresh sewage does not stink, and as its treatment on our Leeds bed is marvellously rapid, only requiring a few minutes, I don't see how any nuisance can possibly arise; while with septic tanks, the septic effluent at least is offensive; and as I found at Accrington in summer weather, is likely to cause a smell, while smell will possibly arise also from the drying of the septic tank sludge. As a matter of relative cost, the Leeds bed arrangement will be less costly than septic tanks, followed by Whittaker beds.

7397. As regards storm waters, is there much to choose between these two systems?—I think not. With trick-

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ling filtration, either preceded or not by the septic tank, the increase of flow due to dilution can be dealt with, and will actually be useful in preserving the filters from becoming choked.

7398. Then briefly you prefer trickling filtration to contact filtration, and you don't think that antecedent septic action is necessary for trickling filtration, indeed that on the ground of probable nuisance arising, such septic action is objectionable?—That is my present opinion.

7399. I take it that in all your answers in this examination you are guided by experience of Leeds sewage?—I wish it to be understood that my opinion is based upon the experiments with Leeds sewage, and that I do not wish to express any strong opinion in regard to other sewages. There are cases of special sewage like those of Bradford and Burton-on-Trent for instance, where the Leeds results would be no guide at all, because of the presence in large volume of special trade effluents in those sewages. Still, Leeds sewage may, I think be useful as a guide for the sewages of many towns where the domestic sewage is mixed with a variety of trade effluents. I am inclined to think from what I have seen of the sewage of Manchester, Birmingham and Sheffield that experiments with their sewages would give results not differing widely from those with Leeds sewage.

7400. What about mere domestic sewage?—From what I have seen of domestic sewage, I think it is easier to deal with than more complex sewage, and greater nitrification will be obtained; but in connection with trickling filtration, without previous septic tank treatment, there would, I fear, be a difficulty, especially in small installations, because when sewage travels only a short distance before reaching the works, paper and fæces arrive in a somewhat unbroken condition, and possibly with domestic sewage the septic tank may be necessary in most cases, in order that suspended solids may reach the trickling filters in a finely divided condition.

7401. As regards the bacteriological features connected with the Leeds experiment have you anything to say to us?—On this point my knowledge is second-hand. I understand that the estimates for Leeds crude sewage give 3 to 4 million bacteria per c.c., and that in septic tank effluent this number is more than doubled, being often 10 million per c.c., while the number in septic tank sludge rises to hundreds of millions per c.c. As the result of filtration of crude sewage or septic effluent the number is largely reduced, but is still large in the final filtrate, especially with coarse material. Where the filtrate is to go a stream not used for drinking purposes, the number of bacteria left in the filtrate does not seem to me a serious objection. In the case of Leeds it is intended to pass the filtrate over land, if the necessary Parliamentary powers are obtained in connection with the Gateforth Estate, and in that case the final result would no doubt be very good as to bacteriological tests. I should prefer that on these points Professor Boyce, who has made examinations at Leeds, should be examined; and I should like to add that Mr. Harrison, the chemist at the Knostrop works, will be glad to answer questions on technical matters relating to the chemistry of our Leeds experiments. And I have here a report by Mr. N. Walker, which I will read if the Chairman desires it, or hand in.

7402. Would it not be as well to have that read?—It seems to me to be rather an interesting branch of investigation which has not hitherto received, I think, much attention. It is a study of the visible growths, not microscopic growths—growths which are obvious to the eye—and therefore I think it might be rather useful to extend this investigation if Mr. Walker had leisure for it. Shall I read this report?

7402* I should think so.

PRELIMINARY REPORT

Upon a Biological Method of determining the purity of Sewage Effluents.

The following Report has been drawn from observations made from September to January, 1900-1, at the Leeds Sewage Works:—

"A good effluent is characterised by an association of organisms, the chief of which, when present in quantity, are easily visible to the naked eye. The following is an account of the principal living forms observed in the effluent from the double contact Dibdin beds, Nos. 1 and 2 (Albuminoid ammonia 0·086 grains per gallon, N. as nitrates 0·36)

"This filtrate is received in a basin with bricked sides, and provided with two Lips. During both the summer and winter months these Lips are coated with organisms characteristic of the effluent which has been flowing over them, and they constitute as it were a register of the quality of the effluent which has passed through the chamber for several days. This living coat in the presence of a good effluent is of a pale green colour, and consists mainly of two green fresh water algæ, Stigeoclinium tenue, Ktz, and Microspora fugacissima, Ag. In addition a variable amount of a blue-green alga is visible upon the lips which appears to the naked eye as dark coloured streaks interrupting the pale green stratum in two or three places. These dark blotches consist of Oscillaria brevis Ktz, and there can be no doubt that their presence serves to indicate that the effluent, although a comparatively pure one, is still tainted with sewage. This view is supported by the fact that an increase of the amount of albuminoid ammonia in the effluent up to a certain point is accompanied by a corresponding increase in the quantity of this species of Oscillaria upon the lip, shown by the widening of the dark streaks. A small quantity of this alga occurs in the effluent from the septic tanks. This effluent, however, is much too foul to support an abundant growth of this or any other algal form.

"The sides of this basin present a clean appearance, and microscopic examination of scrapings shows only a few minute diatoms. In the summer of 1900 an abundant growth of Potamogeton pectinatus covered the bottom.

The filtrate from the Cameron installation, viz., single contact filtration of septic effluent, though much inferior to that produced by the double-contact Dibdin beds, is non-putrescent (Alb. NH_3, 0·157; N as nitrates 0·24). The inspection chamber which receives the effluent presents an untidy appearance due to thick irregular growths upon the lip and sides. The lip is covered by a thick brown coat, which consists of a fungus Cladothrex dichotoma Cohn, with here and there green patches composed mainly of Stigeoclonium tenue. The following algæ occur in small quantities, mixed with the Stigeoclonium:—

Microspora fugacissima, Ag.
Microthamnion Kutzingiana, Naeg.
Oscillaria formosa, Bory.
Naxicula mesolepta Ehr, and other diatoms.

"The following animals inhabit the algal meshwork:—

Chilodon cucullulus. Mull. Lito notus fasciola Ehr. Paramæcium aurielia Mull.	a few.
Chironomus larnac. Rotifer vulgaris Schrank.	abundant.

"The sides of the chamber are covered with a very thick flocculent growth, consisting of a foul water infusorian Carchesium Lachmanni Kent.

"The predominant growth of Cladothrix upon the lip points towards a tainted condition of the effluent. This growth, taken along with the abundant Carchesium, conclusively indicates the presence of a large amount of organic matter, and this is further supported by the presence of the ciliated infusorians, which love organic infusions.

"The occurrence, however, of Stegeoclonium, Microspora, and Microthamnion constitutes a redeeming feature, and serves to show that the effluent is rich in nitrates, and is not putrescent.

"During December a considerable change of organisms took place in the effluent from the Dibdin double-contact beds, Nos. 1 and 2, due to a change in the treatment. These changes indicated in the clearest manner a corresponding deterioration in the purity of the effluent.

"The first indication of failure easily noticeable was a broadening of the streaks of Oscillaria brevis. Microscopic examination of the green stratum revealed the presence of a small quantity of Cladothrix. A few days later a thin growth of Carchesium Lachmanni appeared upon the sides of the chamber. With the Carchesium occurred the following:—

Vorticella microstoma Ehr.,
Vorticella nebulifera Ehr.,
Vorticella putrinum Mull.,
Litonotus fasciola,
Microthamnion Kutzingiana,
Stigeoclinium tenue,
Cladothrix dichotoma,
Rotifer vulgaris.

"Of these may be mentioned the outstanding forms

which accompany an increase in the amount of albuminoid ammonia:—

Carchesium Lachmanni,
Cladothrix dichotoma,
Oscillaria brevis.

When present in quantity these forms are easily visible to the naked eye.

"Ducat bed.—Towards the end of November this bed, through surface clogging, produced a putrescent effluent (alb. NH_3 0·3). This soon became apparent upon the lip of the inspection chamber, which became coated with a layer of almost pure Cladothrix. As the foul effluent continued to pass through the chamber the Cladothrix growth increased in thickness, and in a fortnight from its first appearance hung in brown flocculent masses upon its side and lip. A little Beggiatoa alba Vauch had now made its appearance. In habiting the Cladothrix mesh-work the following infusorians were observed:—

Vorticella microstoma,
Stylonychia pustulata Ehr.,
Litonotus fasciola Ehr.,
Paramecium aurelia.,
Astasia trichophora Ehr.,
Heteromita lens Mull,

and a worm, Acolosoma hemprichii. This association of Cladothrix and infusorians devoid of any algal forms in an effluent well exposed to light indicates a putrescent condition and poorness in nitrates.

"During this initial stage of investigation upon the life in sewage effluents, the following advantages of the method readily determining their purity, outlined in this report, have clearly presented themselves.

1. If an effluent, or a portion of it, be passed through a suitable inspection chamber, it registers its condition upon the sides and lip of the chamber.

2. The organisms present in the chamber register the condition of the effluent which has passed through it for some time, and indicates the average purity of the effluent.

3. The impossibility of inducing the formation of any growth without a corresponding condition of the effluent."

"NORMAN WALKER.

"Yorkshire College, Leeds."

7403. I think you have formed an opinion as to physiological tests in connection with your sewage effluents and filtrates. Do you wish to say anything about this?—Yes. The test as to coarse fish living and thriving in an effluent seems to me valuable evidence of the presence of dissolved oxygen, and the absence of much impurity. At Leeds the filtrate from each separate experiment passes through a brick basin about 10ft. × 6ft., with two lips, which form little reservoirs of 2ft. and 4ft. depth. These are reception chambers retaining some of the effluent which has passed. The bottom of the chamber was formed of white glazed bricks, and when kept clean showed off the filtrates to best advantage. But I soon found it necessary to give instructions that these basins were on no account to be cleaned or disturbed, so that one might investigate the growth which formed on the lips and on the walls. I have formed a strong opinion that the character of the growth in these outflow basins and in the channels through which effluents and filtrates pass, offer to the eye an obvious general test of the character of the fluid passing over or through them. In the case of sewage or septic tank effluent, we find grey and light and dark brown growths, which are characteristic of impure conditions, while in good biological filtrates we find green growths which we associate with relatively good conditions. I was much interested in this matter, and instructed Mr. Norman Walker, of the Biological Department of the Yorkshire College, Leeds, to prepare for me microscopic slides of the animal and vegetable features connected with our basin, and recently he has been investigating for me some of the growths, and prepared the preliminary report, which I have just read. He reaches the conclusion that in passing through a basin or channel an effluent registers its condition on the sides, and that the organisms, fungi, algæ, infusoria indicate the average purity of the effluent which has passed. A growth cannot be induced without a corresponding condition of the effluent. I think the subject well worth further investigation. We found fish to live well in our best filtrate. One particular brown carp has been living in one of our filtrate basins since October, 1897. Frogs, too, sometimes make their home in the basin for long periods.

7403*. Perhaps I might just ask you one question as regards the chemical analyses. Could you tell us on what number of observations the averages which you have given us are based?—Yes. *Col. Harding.* 5 Mar. 1901.

For No. 2 contact bed on 163 analyses.
" 4 " 151 "
" 6 " 75 "
" 7 " 24 "
" 8 " 38 "
For No. 1 septic tank effluent on 95 analyses.
For Cameron process on 54 analyses.
For No. 1 Whittaker bed on 82 analyses.
" 2 " 111 "

7404. (*Professor Ramsay.*) What is the size of this bed you have been talking about?—The Leeds bed is 17 square yards. It is our old triplicate bed.

7405. Yes?—Well, this triplicate bed was transformed into the single bed by keeping the third triplicate, and building up its walls sufficiently high to receive the coke from I. and II. in one column. The same material was used. I have here some samples, which may be of some little interest.

7406-7. (*Major-General Carey.*) Does the fine material account for the superiority of the analysis of the Ducat filter, on page 29 over the Whittaker filter?—It does undoubtedly account for the admirable result which we get on the Ducat bed, when it is working well. We get distinctly the best results on the works from the Ducat bed when it is working well, but those good conditions cannot be maintained, because after about a month the surface becomes clogged, then you get a deterioration, and the deterioration is so complete that if you let it go on, say for six or seven weeks, what comes out analyses nearly as bad as the crude sewage which goes on.

7408. Your Leeds bed is rectangular, and with a circular sprinkler?—Yes.

7409. When the sprinkler revolves, is not part of the sewage carried completely over the filters?—Over the corners?

7410. Yes?—It is not on the surface. The corners on the surface are quite dry.

7411. The sprinkler is inside the rectangle?—The sprinkler has a circular action of about 4 yards diameter, and the coke is square, 4 yards square, and there were, therefore, corners which are not sprinkled at all, but the sewage undoubtedly spreads over the corners as it gets down in depth. We have assumed, as you will see in one of my answers, that the distribution becomes complete at about half depth, and, therefore, in our calculation we have taken half the difference between the circular and the square area, and we have calculated the 400 gallons and the 200 gallons per square yard upon such medium area.

7412. Why do you expect to get these more permanent results in the "Leeds" than you have in the Whittaker or Ducat filter?—I do not expect.

7413 You say the life of the filter is more permanent?—I do not think I have said the life of a filter constructed as the Leeds filter will be greater than that of the Whittaker bed, because I do not think there would be any difference. The construction is very similar; it consists of coarse material. I think both of them would last equally well. The only difference is that in the Leeds bed we are dealing with septic effluent; and I was very anxious to see whether the antecedent anaërobic treatment was a necessity, or whether it would be possible by trickling filtration over coarse material to bring about the results obtained by the Whittaker bed without the previous septic treatment, and I think the experiment shows that these results can be brought about without the anaërobic action.

7414. (*Professor Ramsay.*) Have you ever tried the Whittaker sprinklers cold?—Yes.

7415. Does it make much difference?—We tried in the first instance the Whittaker bed not only with the increase of temperature caused by the pulsometer, but with an additional injection of steam, and we found that that was an excessive rise of temperature, and would obviously be too costly, and after a while we gave it up. Then we worked for a considerable period with the increased temperature due to pulsometer, and finally, desiring to know in the case of the Whittaker whether we could pass through this winter without any artificial heat at all, we removed the pulsometer and substituted a donkey pump, in which the condensed steam does not mix with the sewage, in which there is no increase of temperature due

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to the pumping. I have been away from Leeds during the severe weather. Mr. Harrison, perhaps, will be able to tell you whether the Whittaker bed has given deteriorating results during the recent cold weather. I should expect that it would.

(*Mr. Harrison.*) Yes, the results have inclined to become opalescent during frost. The nitrification has decreased, but the effluent as a whole, just as it comes from the filters, has been nonputrescent in every case; the solid matter settled from the effluent, however, has been putrescent.

7416. Is there much solid matter?—About 5 to 7 grains per gallon.

7417. The same as there was before?—Yes. (*Colonel Harding.*) And the results Mr. Harrison has been referring to are exactly the same as those I have been giving in connection with the Leeds bed. The construction of the bed is the same, and naturally one would expect that the effect of frost would be the same in both.

7418. Are there any data as to the actual cost of treating?—There are no data as regards Leeds, but there are as regards Accrington. When I was at Accrington I asked questions from the engineer there, and Mr. Whittaker. The cost of heating the sewage at that place will be found in the evidence.

7419. Is it very considerable?—If I remember right, speaking quite from memory, it was about £700 a year for the Accrington sewage.

7420. Much the same expense for the pumping without heating as the cost of a donkey pump and injector?—I think it would be cheaper to pump with the ordinary pump than with pulsometers.

7421. With your own Whittaker bed, the circular one which we know, are the periods of clogging coming more closely together and getting more frequent; does it require washing out more frequently than it did?—Do you mean the Whittaker bed?

7422. The Whittaker bed?—It has never been washed out but once; the coarse Whittaker bed has only been washed out once.

7423. I mean the circular Whittaker bed?—There are two circular Whittaker beds.

7424. I mean the old one?—The old one cannot be effectively washed out, it is too fine. At the present moment it is out of work. The second one, the coarse one, has been successfully washed out.

7425. Once?—Once. It has only required it once, but as I pointed out in my answer in referring to that question the washing out would take place automatically by the increase of flow during storm times, and that appears to me to be a very interesting thing in connection with trickling filtration, that storm waters may be dealt with in larger volume, not only without damage, but with positive advantage to the bed; that at such times accumulations of indigestible solids in a bed will be washed out.

7426. Would the effect of storm water going on to a Whittaker be to make the arms go round more rapidly?—With a Whittaker sprinkler it would be to increase the flow through the holes, and, therefore, to promote the rotation of the sprinkler.

7427. Would you work the pulsometer more rapidly?—Necessarily if there was more to pump the pulsometer would have to work more rapidly.

7428. Then that would involve constant attention, of course?—The cost of pumping would be in proportion to the volume pumped.

7429. Naturally, but I mean someone would have to be on the outlook, without there is a storm overflow to regulate the pumping accordingly?—Certainly, the pumping must be regulated to the volume passing through the septic tank. That is an advantage of the Candy sprinkler, that its increase is automatic. The head is not a large head, and as the volume passing on is greater, the times of intermission between the sprinkling become shorter.

7430. Is it the case that the suspended solids of the Whittaker bed effluent are not usually putrescent?—They are not usually putrescent, but, as I said just now, they have been putrescent during this severe cold weather.

7431. Has this been tried anywhere else except at Leeds?—Oh, yes, the Whittaker system is tried on a very much larger scale than at Leeds at Accrington.

7432. I know, but is it found that the suspended solids at Accrington are putrescible?—At Accrington Mr. Whittaker told me that they are not putrescible, but I understand from experiments recently made by Mr. Frye that they are found to be putrescible.

7433. Mr. Frye, do you corroborate that?—(*Mr. Frye.*) Yes, on all occasions I found them putrescible. (*Colonel Harding.*) Is it because of the iron at Leeds; is that the reason? (*Mr. Frye.*) That is possibly the reason why they are not at Leeds and they are at Accrington.

7434. (*Mr. Killick.*) They are found to be putrescible at Rochdale, I believe?—(*Colonel Harding.*) It is fair to add that at Accrington they are working at double the rate we are at Leeds; they are working at 400 gallons per square yard, and the time of passage of the solids through the filter ought to be correspondingly reduced, and there would not be the same time for the change to take place. I think the non-putrescibility of the solids at Leeds may be due, in large part, to the fact that the flow is slower at Leeds than it is at Accrington.

7435. (*Professor Ramsay.*) Is it proposed to press the sludge from the Whittaker beds?—Do you mean at Accrington?

7436. At Leeds?—No; there would be no objection to pressing the sludge, but the idea at Leeds will be to pass the filtrate over land. The Corporation of Leeds has secured a large estate, and the idea is that if the Whittaker bed were adopted, following the septic tank, or the Leeds beds were adopted without septic tank, the effluent, containing, as it does, a considerable amount of suspended solids, will be passed over the land; those suspended solids which are usually nonputrescible will remain on the surface of the land, and be ploughed into it, and all you would require of the land would be this mechanical separation of the suspended solids, and a very trifling purification, because the main part of the purification will have been accomplished before the effluent reaches the land.

7437. (*Major-General Carey.*) At what rate of flow of the Whittaker bed? I think Mr. Whittaker said in regard to the flow of 400 gallons, that the sprinklers would not work unless the pulsometer were working at that rate?—I think what he said was that his pulsometers would not work at a lower rate. Of course, by changing the pulsometers you could get pulsometers which would work at a lower rate; but if he had reduced the rate from 400 to 200, it meant doubling the area of the installation, and doubling the cost of the installation, and he considered that the results obtained at the 400 gallon rate were good enough, he hoped, to satisfy his authority.

7438. There was no difficulty about it?—I do not think so; it is a mere question of changing the pulsometer.

7439. (*Professor Ramsay.*) Before we leave the subject: has anything been done as regards removing the iron?—I am bound to say that since we have taken to trickling filtration we have become in a manner reconciled to the presence of the iron.

7440. It would not be possible to make temporary experiments by removing the iron?—It would be possible, but it would be costly. I intended at one time, I think I mentioned it to the Commission, to try the experiment. I found the cost would be probably £500 to try it. It would mean that the effluent from the large works whence this iron comes would have to be conducted direct to the river, a considerable distance, and I found the cost would be about £500 to do that. I could get the permission of the Rivers Board for it to be done experimentally, but we came to the conclusion that it would be hardly worth the expense.

7441. (*Dr. McGowan.*) Would it not be worth the trouble, because you have been dealing with sewage containing both fibre and iron, and that would enable you to say which produces the clogging, the fibre of iron?—The fibre scarcely comes in in this Leeds bed experiment, because it is screened off.

7442. It struck me as being a very interesting point practically?—We screen off the fibre, and in regard to the iron, the removal of the iron which comes from these particular works would not do away with all iron in our sewage. Iron reaches the sewers from a considerable number of sources, and it would be I suppose quite impossible to keep iron out altogether; and in trickling filtration iron does not seem to do any serious damage beyond increasing, to some extent, the volume of the suspended solids, non-putrescible solids, in the

filtrate, and no doubt to a certain extent taking up oxygen which would be useful in dealing with organic matter.

7443. (*Professor Ramsay.*) Have you given the results of analyses of the Whittaker beds effluents in a table?—Yes. Those you will find fully detailed in answer to Question 7369.—"Q. Have you any analyses of the filtrates of your No. 2 Whittaker bed?" I have put in a table and you will find a comparison of the same filtrates with and without the suspended solids.

7444. Could Mr. Harrison give me the figures for the worst effluent you have had? These are averages, what is the worst result?—With all the solid matter in it has been from ·3 in albuminoid ammonia.

7445. That is during the past winter?—No, I have never had it so bad; during the last winter it has never been above ·25.

7446. I suppose you regard side aeration to be desirable?—(*Colonel Harding.*) It seems to me to be of no value whatever. The moment the surface becomes clogged the results become very bad indeed.

7447. Would not that simplify the construction?—In the Leeds filter we have no side aeration.

7448. Is it in fact a Ducat filter without side aeration?—That is so. The principle of the Ducat filter is the same as the Leeds filter; it is trickling filtration of screened sewage. The reason why the one is permanent and the other only transient results is that in the one case the material is coarse, and in the other the material is fine.

7449. Is there no breaking down?—Of the material? I have not been able to get that, but I should say for practical purposes there is no breaking down, because the coke is not disturbed in any way.

7450. I suppose there is no breaking down in the Whittaker beds?—No, very little; there is breaking down in the surface, which may be due to atmospheric action; but it is mainly due to walking over the bed to attend to the sprinkler. Constant walking over the bed, there is a little crushing down of the material on the top, but the degradation of the material takes place to a greatly less extent in trickling than in contact filtration. We were very much struck with that. During the period we used our triplicate bed as contact beds there has been no apparent change in the material for a long period, used as trickling beds, but during the week that we used it for contact filtration the effect was very remarkable. We found coke floating on the surface, and we found that it rose and then sank again, and in some parts the surface sank as much as a foot.

7451. There has been no sinking in the Whittaker beds?—No, nor in the Leeds bed. It is difficult to see how it could arise; there is no change in the conditions.

7452. How are you distributing on to your Leeds beds?—By means of a Candy sprinkler.

7453. Do you prefer that to a Whittaker?—Yes, although the Candy sprinkler has the disadvantage of being intermittent, and causing the sewage to pass through in rushes. To that extent it is a disadvantage. On the other hand, the Candy sprinkler has this advantage, that while it works, it works at a greater pressure, because out of five minutes it only works one minute, and whereas the same volume would be spread over in five minutes by the Whittaker sprinkler, that volume passes through in one minute by the Candy sprinkler, and while it works at a greater pressure the holes are more easily kept clean. It does not want so much attention, and it also works with a smaller head. Incidentally there may be this further advantage in the use of the Candy sprinkler for use with crude sewage, that the intermittence has some effect in choking the growth of the pilobelus on the surface.

7454. Which tends to block the surface?—Which tends to block the surface in continuous filtration. I recently visited Bristol, and I saw there the effect of the rain dropping system of Mr. Stoddart, and there was there a pilobelus growth upon the coke, but the sewage that he is dealing with is so exceedingly weak that it was not excessive, it did not interfere with action, but if we had continuous trickling with the Leeds sewage at anything like the rates which are being used at Bristol, I am quite sure we should have a pilobelus growth which would stop the action before very long.

7455. Is there not a very great amount of cleaning and poking out of the holes necessary in connection with the Whittaker?—Very considerable. I believe we are obliged to clean them out almost daily. The rush of water through the holes is very slow on account of the small quantity which passes on 200 gallons per square yard working continuously, and it requires constant attention, and the mechanical contrivance of the Whittaker sprinkle is very far from being satisfactory.

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7455. And as to cost of picking out?—Not only serious, but almost prohibitive.

7457. And the Candy sprinkler?—With the Candy sprinkler the trouble would be considerably less, but I hold the opinion that as yet we have no satisfactory system of distribution upon continuous beds. No doubt the idea is to have a distribution of sewage equally over the whole surface. You get that in the Stoddart, but I am afraid that would not act effectively with sewage containing any considerable amount of suspended solids.

7458. Is there much raking out of the Stoddart sprinklers?—The Stoddart distributor requires very frequent attention at Bristol.

7459. The gutters fill up?—The gutters fill up. At Leeds I am quite sure that they would require daily attention. I may add that since my visit to Bristol we have ordered a Stoddart distributor, and we are going to put up a small bed so as to test the advantages, if any, of the Stoddart distributor.

7460. Do you propose this Leeds filter as suitable for other sewages besides Leeds, or is it specially adapted to the special sewage of Leeds?—It is a very interesting experiment. I think it would be applicable to other sewages, but I think I have said in some of my answers that I should doubt the possibility of putting domestic sewage of small installations direct upon such a bed, because I find that in small installations, where the sewage travels a short distance before it reaches the works, the fæces and paper and so on reach the works in practically an unbroken condition, and it would be impossible to put those in such a form upon the bed, and to attempt to screen them off you would screen off everything.

7461. Would you advise a septic tank and then the Leeds beds?—I think in the case of domestic sewage a septic tank is almost necessary for the purpose of breaking up the suspended solids into a finely divided condition.

7462. And after that the Leeds bed?—And after that it would become a sort of Whittaker bed.

7463. Except that it would rest upon the ground?—Yes. In the case of Leeds I must say I do not see that there is any necessity for antecedent septic action, and if it proves practicable, as I think it will, to devise an automatic screening apparatus to take off the grosser solids, I think it would be possible to put crude sewage with finely divided solids direct upon a continuous filter, and then have a settling tank at the end of the process, instead of at the beginning, or if land is available, as it would be probably for the Leeds works, pass it over land for the purpose of mechanically separating—filtering the suspended solids.

7464. You do not anticipate having to clean out those Leeds filters to any extent?—I think not, because if accumulations take place, and no doubt accumulations take place at the slow flow, we found that with the Whittaker bed we were able absolutely to wash out the bed.

7465. Do you think this is the end of the Leeds experiments, or are you prepared to carry them on?—Oh, no; undoubtedly we are prepared to go on very steadily with our experiments, especially in the direction of septic tanks, trickling filtration of septic effluent, and trickling filtration of crude sewage.

7466. You will continue your experiments at Leeds?—Oh, undoubtedly. After our experience of the Leeds beds our intention is now to construct a Leeds bed on a very much larger scale.

7467. To deal with what proportion of the sewage?—Oh, quite a small fraction of our sewage. Our spare ground there is so small; the place at Knostrop is almost wholly taken up with our chemical precipitation, and all we can deal with is a part of our sewage.

7468. Could you not move to the new site?—The position of affairs in regard to Leeds is that we are applying to Parliament; the matter is to be heard by a Committee of the House very shortly, for power to carry our sewage to Gateforth. There is considerable opposition which we will have to fight. If we obtain these powers, it will be several years before our conduit can be constructed, and therefore we shall have ample time to complete our experiments at Knostrop, so that in three or four years, when the conduit brings the sewage to Gateforth, we shall have seen what it is that it is best for us to do.

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7469. May I ask whether, without a septic tank, the variations in the Leeds sewage show in the effluent, using the Leeds filter?—Undoubtedly they would show in the effluent. We are getting at the moment a very strong sewage. We could not get so good a result as at those times when a very weak sewage is passing; and then at times we get a good deal of dye and other matters. They would be bound to affect the result, but the average would come to the same.

7470. But do you not consider the advantage of equalising the flow, equalising the character of the sewage would compensate for erecting a septic tank, although it may not be necessary?—No doubt an advantage of the septic tank is that it would equalise the sewage, but I scarcely think it would be necessary to go to that expense on that account only, if no inconvenience arises to the filter by those variations.

7471. (*Mr. Killick.*) We found in the Mersey and Irwell that our limit of manufacturing purification, 5 grains of solids took out virtually the whole dyeing matter, not above one or two per cent. of effluents complying with that will discolour wool in the test tube?—That is in regard to the solids.

7472. Yes, in regard to the arrest of the solids?—In regard to Leeds we find that in trickling filtration, if the sewage going on is deeply coloured with dye, the filtrate is not coloured.

7473. That arrests the solids in suspension, in the filter?—No, it is a decoloration of the liquid. I do not think very finely divided colour is floating in the liquid.

7474. That is what you find from practical experience?—In the case of aniline dyes, a most minute fraction of the aniline dye will colour or discolour an immense volume of liquid.

7475. That is exactly our experience, that our limit of five grains of solids in suspension will take out all the ordinary aniline dyes.

7476. (*Professor Ramsay.*) Might I take this opportunity of asking Mr. Harrison some questions? What is your view, Mr. Harrison, as regards the values of the oxygen absorbed test and the albuminoid ammonia test, and the incubator test taken separately or together?—(*Mr. Harrison.*) The albuminoid ammonia test, I think, is a very good one, especially when the Rivers Board standards are taken into account. That is one grain per gallon of albuminoid ammonia to be their limit. This applies especially to contact beds. A contact bed which gives an effluent over that in value I certainly am rather dubious about. But with regard to continuous filtration, it very often occurs that an effluent is produced with a value in albuminoid ammonia very much over the standard. An effluent of that character contains a large amount of suspended matter, and is absolutely non-putrescent.

7477. So that you do not regard it as a complete standard?—No. With regard to continuous filters, of course, if it is necessary to fix a standard as to the amount of suspended matter present in a continuous filtered effluent, say fixed at 2, 3, or 4 grains per gallon or less, then the Rivers Board standard would come into play.

7478. Then taking the oxygen absorbed test, what is your opinion of that?—Well, I find that it runs very parallel to the albuminoid ammonia in effluents.

7479. That you may have an effluent taking far too much oxygen, and yet be non-putrescible?—No; I find that a sewage is more easily purified with regard to the oxygen absorbed test than with regard to the albuminoid ammonia, and it is only very rarely, and only with regard to fairly bad effluents, that the oxygen absorbed ever gets above 2 grains per gallon. In that case the effluent is unsatisfactory.

7480. Then the incubator test—do you consider that a good one?—Yes; I have found with experiments on the Leeds sewage that simply dependence upon the increase of oxygen absorbed in three minutes can hardly be relied upon. I have had effluents which have increased in oxygen absorbed in three minutes on incubation but which have developed absolutely no smell. On the other hand, I have had effluents which have developed a bad smell, and have decreased with regard to the value. I find myself that it seems to be far better to put the real criterion of the test on to the smell and not on to the oxygen absorbed in three minutes unless there is a decided increase.

7481. Have you tried any bacterial methods of testing?—No.

7482. I mean not counting the number of bacteria on a filter paper, but see whether there are any?—You always incorporate that with the incubator test.

7483. Have you tried experiments with gelatine, or anything of that sort?—No.

7484. But do you not agree that the final test should be whether the effluent will or will not putrefy?—Yes; that is the great test.

7485. Then it is not necessary to use a chemical test if you can get a bacterial one to show that?—Well, I am rather doubtful about that point.

7486. You would like to keep both?—We have effluents which are non-putrescent, but which cannot be looked upon as good effluents such as the effluents from our Cameron process.

7487. Is there any test or anything that you can suggest which would enable one to judge as to the goodness or badness of an effluent which could be put into the hands of a workman?—I can only suggest the incubator test, without incorporating the estimation of the oxygen absorbed, that is simply to see whether the effluent produces a bad smell or not.

7488. Have you considered the question of standards?—We always work at Leeds on the Mersey and Irwell standard.

7489. Do you consider that satisfactory?—Quite satisfactory with regard to settled effluents from continuous filters and effluents from contact beds.

7490. When is it not satisfactory?—If you take into account the effluent from a continuous filter unsettled.

7491. Unsettled?—Yes.

7492. Is that generally known, or is it your own individual opinion?—It is an opinion I have got from analyses of the Leeds effluents from the Whittaker beds, the triplicate and the Ducat.

7493. Then you are quite content to stick to the Mersey and Irwell standard?—With that reservation.

7494. With the reservation you have made?—Yes.

(*Colonel Harding.*) There is just one point I should like to bring out if I might be allowed to ask Mr. Harrison a question, and that is, I think Mr. Harrison that the usual composition of suspended solids in crude sewage you find 60 per cent. organic and 40 per cent. mineral?—Yes.

7495. In suspended solids in the septic tank effluent you find about 47 per cent. organic and 53 per cent. mineral?—Yes.

7496. And in the suspended solids in the Whittaker filtrate you find about 40 per cent. organic and 60 per cent. mineral, therefore as the process is completed there is a reduction in the proportion of organic matter as compared with mineral?—Yes.

7497. But you do not think, do you, that one can argue much upon that score, because the data warrant on the one hand the supposition that there is a larger consumption of organic than mineral matter. They would also warrant the supposition that there may be an increase of mineral matter by passage into suspension of mineral matter which had been in solution?—That is so.

7498. But it is nevertheless an interesting fact that as the process continues the relation of the organic to the mineral matter is steadily decreased?—Yes.

7499. (*Chairman.*) But that is what one would have expected, is it not?—(*Colonel Harding.*) Naturally, yes.

7500. But is there no fear that the minerals will gradually clog up the surface so that you cannot wash them out in this simple way?—I do not think there would be any difficulty in the case of a coarse filter, because the suspended solids in that filter do not seem to adhere to the surface of the material.

7501. You consider you have got enough experience to show that?—Well, washing out is so immediate. If you hold the sprinkler so as to prevent its rotation within two minutes you get a turbidity of the effluent, showing that the suspended solids in the filter, the accumulations in the filter are in a granular form, which at once wash out the moment there is an increase of flow. The action is immediate, and when we tried that very interesting experiment in washing out the Whittaker bed we tried turning a hose upon a square yard in the first instance. Well, almost immediately, within two minutes or less the flow was extremely turbid, and so turbid indeed that in a test tube containing 10 inches of it there would be a settlement of 3

inches deep of sludge. We gathered from that that the accumulations in the filter could be very readily washed out by increasing the flow.

(*Chairman.*) Colonel Harding, I hope you will allow me on behalf of the Commission, to thank you most sincerely for your very valuable evidence, and perhaps one might take this opportunity of expressing one's admiration for the energy Leeds has displayed on those questions. *Col. Harding.* 5 Mar. 1901.

TWENTY-NINTH DAY.

Wednesday, 6th March, 1901.

PRESENT:

The Right Hon. The EARL OF IDDESLEIGH (*Chairman presiding.*)

Sir MICHAEL FOSTER, M.P., F.R.S.
Mr. W. H. POWER, F.R.S.
Major-General CAREY, R.E.
Professor WILLIAM RAMSAY, F.R.S.
Colonel HARDING.
Mr. T. W. KILLICK.
Dr. J. BURN RUSSELL.

Mr. F. J. WILLIS, *Secretary.*

PRESENT ALSO:

Professor BOYCE.
Dr. G. McGOWAN.

Mr. GEORGE RICHARDSON STRACHAN, called in; and Examined.

7502. (*Chairman.*) I think you are Mr. George Richardson Strachan, an engineer?—Yes.

7503. And you have had a good deal of experience in partnership with Mr. Mansergh, in sewage and water engineering?—I have.

7504. Can you mention any places where you are carrying out schemes of sewage disposal?—Yes, at Plymouth, where we are turning the crude sewage into the Sound after it has been stored up in a tank; at Exmouth, where the crude sewage is discharged into the sea continuously.

7505. Where it is discharged into the sea without any preliminary treatment?—Yes, the crude sewage.

7506. Simply crude sewage, without any treatment at all?—Yes.

7507. (*Mr. Power.*) At all states of the tide?—At Exmouth, at all states of the tide. At Coventry, broad irrigation, after passing through upward straining tanks.

7508. (*Chairman.*) May I ask you what your definition of "broad irrigation" is?—I would define broad irrigation as the application of sewage to land after it has undergone some preliminary straining where the area is considerable in proportion to the quantity of sewage to be dealt with, and I add those latter words to distinguish it from the application of the same sewage to land which is under-drained and applied intermittently, commonly called "intermittent downward filtration," although I do not know exactly what that means.

7509. With broad irrigation would you mean that the sewage was going continuously over a large area of land?—Yes. In broad irrigation about 1-10th of the area of the farm should be under water at any particular moment.

7510. Yes?—Then it is moved about from place to place, every fortnight or ten days or a week, as the case may be; not the whole area under water at once.

7511. (*Sir Michael Foster.*) No, but the same area is under flow for ten days or a fortnight continuously?—Yes.

7512. (*Chairman.*) Then in reality there is no essential difference between that and intermittent filtration?—There is no essential difference, I think; that is quite correct. I would say that intermittent filtration consists in the artificial preparation of the land by under-draining to facilitate the passage through it, and therefore you get more through per acre than you otherwise can do by simply passing it over the surface if you have no underdrainage, but there is no essential difference that I know of. Then, at Mountain Ash, I am also carrying out a scheme on the same principle as at Coventry. At Aldeburgh I am carrying out another scheme, in which the sewage is turned into a tidal river after passing through double contact beds. At Hassocks I am carrying out another scheme in which the sewage will be carried through double contact beds and then over stiff clay land; and at Andover I am finishing a scheme that another engineer devised of septic tanks, contact beds and land treatment, and I took that up merely to find out by personal experience the capabilities of that system. *Mr. G. R. Strachan.* 6 Mar. 1901.

7513. I suppose in these cases your experience is not at present sufficient to enable you to say anything much about results?—No; I have an engineer's view on those subjects. I have seen them, but my opinion is worth nothing on the subject as to results.

7514. Have you any knowledge of the bacterial system? Yes, I have from the engineer's point of view made a critical study of the one at Exeter, at Yeovil, and Sutton, and Hendon (that is, Colonel Ducat's), at Wolverhampton, Barking, Salford, Nuneaton, and Chorley, and generally I have informed myself about others, but of those I can speak upon critical examinations from an engineer's point of view.

7515. Can you tell us any general conclusions that you have arrived at?—Yes, I regard them as very helpful means of dealing with domestic sewage; very helpful indeed, and I think that for some manufacturing wastes, as far as my experience and observations go, they also are useful. That is the general conclusion that I have arrived at; I think highly of them.

7516. Well, now, those processes, I suppose, artificial filtration is certainly included in all of them?—Yes.

7517. In some or all of them there is preliminary treatment to the artificial filtration?—Yes, in several of them.

7518. Do you consider that that preliminary treatment is desirable?—Well, I do not say that it is essential. I think it aids the contact beds or the continuous filters very much, and in my own practice I put it in when I get the chance. I do not bind myself that it is essential, I think it is useful and advisable to have.

7519. I suppose you might say that preliminary treatment means the getting rid of a large quantity of the solids before the sewage gets on to the filter beds?—Yes, that is the main object as I understand it.

7520. Have you got any preference as to the mode

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of keeping back those solids?—Yes, I think I have formed a preference; now, I would, given a free hand, put in tanks that would hold a day or a day and a half's flow of the sewage and let it pass through what is commonly known as the septic tank, although not necessarily in that particular form, because I think it will get rid of a considerable part of the solids and prepare the sewage for the subsequent treatment. In that opinion I am guided by the bacteriologists whom I have consulted as to the effect, and by my own observation, which as an engineer leads me to think that it is useful.

7521. Then you would prefer settling tanks to screens?—A large screen I regard as essential whatever system is adopted. Under any circumstances, whatever you do, I regard screens as essential, unless you pass them through such sedimentation tanks as I have spoken of.

7522. If it was a choice between screens and settling tanks, would you prefer settling tanks?—I think so; I have no doubt of it.

7523. Would your experience enable you to express a preference either way, for open or closed septic tanks? I have no direct experience, but my preference goes for closed tanks. I think such a thing closed up is better than open, and the cost is not much to put a light roof on.

7524. On the question of providing for storm water, can you give us any ideas on that subject?—Yes, I should be very glad to.

7525. It seems a very difficult matter?—I was the surveyor of Chiswick, in 1883 and 1884, where there was what we now know as a "separate system" in operation. No road-water whatever was taken into the sewers, not a drop, and only the water from the back roofs and such portion of the paved ground behind the houses as was connected with the sewers. I kept very careful records at the pumping station of the quantity sent down in times of rain, and I can put before the Commission the facts if they care to have them; I do not know quite how far you want to go into it, but, broadly, I will state the conclusions. My experience there, was that the average area contributing to the sewers for a house was 450 square feet. It is a back roof, the roof of the outhouses, and the bit of paved yard. From that we used to get down at the sewage works rain equal to 300 gallons per head per day; I can give you plenty of illustrations. On the 29th January, 1883, there was a rainfall of ·40 of an inch. I cannot tell you the time the rain occurred, because I had not the self-recording guage, but that was the quantity of rain that fell in the day, and on that day for more than an hour the rain came to the works at the rate of about 170 to 180 gallons per head. On the 10th February in that year there was ·52 of an inch there, and twice in that day the rain came at about the same rate.

7526. (*Sir Michael Foster.*) Came down to the pumping station?—To the pumping station. On the 11th February, which is a very striking case, there was only ·23 of an inch fell, less than a fourth of an inch in the 24 hours, and yet three times in the day was one set of pumps overtaxed, and I had to call in the reserve. One set of pumps raised 150 gallons per head of the then population; and three times in the day the flow, for an hour, another 1½ hours and yet another hour, was at the rate of about 170 to 180 gallons per head. I could give you many illustrations. It occurred again on the 14th July, the 31st August, the 29th September, and many others.

7527. (*Mr. Power.*) Were the works close to the population in those instances?—Within 1½ miles, sir. The thing that used to strike one was the rapidity with which the water was shot down the sewers; coming from slates and concrete it no sooner fell than it was in the sewers.

7528. Was there a very steep gradient in the sewers?—No, sir; because Chiswick is as flat as this table, and everything had to be dug down, and the engineers did not go for steeper gradients than they were compelled. I have one, a particular storm I would like to mention to the Commission. In April, 1885, there fell ·71 of an inch in the day. It caused an enormous rush of water to the pumping station, and for one hour during that time it came down steadily at the rate of 300 gallons per head per day. It came down faster for the first rush, but steadily for an hour. My two sets of pumps were just able to hold the water. I could multiply instances. Here, again, is another which was given to me after I left Chiswick by the manager of the works, on July 21st, 1899, when for five hours the effect of the rain storm was to send to the pumping station 300 gallons per head per day. Supposing you put the sewage at 25 gallons per head per day, that is what we now call twelve volumes, and what I want to impress upon the Commission, and this seems to me to be the whole point, that that came solely from the back roofs. Now, the total quantity of rain that was sent down in the course of the year was very small compared with the quantity of sewage. It did not come to 1-5th. I have one or two figures which I have worked out, which I may mention, which will put this, I think, very clearly. Supposing that in a town in which the back roof area of 450 square feet alone is connected, there is a rainfall of 30in. in the year, and suppose further, which I think is rather an exaggeration, that every drop of that got down to the sewers—I think most of it would come in times of storm, but not all of it, because some rain comes which scarcely wets the roofs, and evaporates. Take it that it all got down, that would mean that from that one house there would be a contribution of 7,031 gallons with sewage. Now take it that there are five persons living in that house, and that the sewage equals 30 gallons per head, they would send to the sewage works 54,750 gallons per year, so that although the proportion of the total rainfall would only come to about 1-7th or 1-8th of the sewage in the course of the year, yet the rate at which it would come down in particular storms would be as much as twelve times what the dry weather flow would be.

7529. For a short time?—For a few hours, sir.

7530. And as to overflows on those sewers?—We had none. We had one at the sewage works which led direct into the river, but it was tidal, and was very little use. We therefore were dependent entirely upon the pumps, and that is how I was able to keep those records so carefully. I do not know that I have made my meaning clear yet. Let me try again. The point that this teaches me as engineer is, that while the rainfall in the course of the year may be only 1-7th or 1-8th in volume all told of the dry weather sewage itself, yet that rainfall may come down at odd times at the rate of twelve times what the sewage itself comes.

7531. (*Chairman.*) Now, might I ask you this: Suppose you had a free hand to put up an artificial drainage system, how would you treat the storm-water?—I take a gravitation scheme because it simplifies the matter; there is not so much difficulty as there is with pumping. I would, according to my present view, put down disposal works that would deal effectively with about 80 gallons per head. I would then put up an effective by-pass upon my sewage works which would effectually prevent that quantity being increased by more than, say, 5 or 10 per cent. I would throw the rainfall over, out of the regular sewage works.

7532. You would only allow an addition of 5 or 10 per cent.?—Upon my 80 gallons?

7533. Upon your 80 gallons?—Yes; of course that is having allowed, I think, about two times the dry weather flow of sewage. That by-pass arrangement can be very easily done by a very long weir; it is very easily done.

7534. This is a separate system you are speaking of now?—I do not mind which.

7535. You do not mind which?—That is my present opinion. I would never send into my disposal works more than that quantity if I could avoid it. I am having a free hand for the moment now. I do not quite know how I should justify the opinion, but my practice is to pass the storm water through coke filters or burned ballast filters, not by putting it on the top and letting it run through, but by putting it on the top, and making it go down and then rising up in the outlet.

7536. (*Mr. Power.*) Then you would have separate filters for the storm water?—Certainly, separate auxiliary means of dealing with the storm water. I think that is a first requisite in effectively dealing with these large quantities.

7537. And in effect, double filtration of the storm water?—Single, sir.

7538. I understood you to say that you would make it go down and then come up again?—I have not made it clear, sir. May I illustrate with a box? I would let storm water come in and go on to the filtering material. It would then fill it. It would have under-

drains, and a man-hole shut off from the filtering material, the walls of which came up above any level to which the storm waters could rise. The drains would all discharge into the manhole, and the water would run over a weir quite separate, so that the action would be to go down, and then to go over the weir, not up through the filtering material. The object I had in my mind in that was this: If you turn storm water on to a large filter of porous material and have the outlet at the bottom, the stuff simply gallops through in the shortest way that is possible; whereas, if you compel it to come out over the top, you are certain first of all that you fill your filter, and second, that the storm water, in going through, actually has the benefit of every inch of the space in the filter which effects clarification or straining. It is really a little engineering detail, but it is what I do in my practice. Then, sir, having got it through there, I would apply it to land—put it over the surface.

7539. (*Major-General Carey.*) The storm water?—The storm water.

7540. (*Colonel Harding.*) To what extent would you deal with the storm water above 80 gallons—beyond the 80 gallons you are proposing to deal with at the ordinary crude sewage works?—I think having a free hand, and not being troubled with any departments or anything, I would fix my overflow levels at 120 gallons per head per day. May I finish what I have to say on that?

7541. (*Major-General Carey.*) When you say "not being troubled with any departments," do you mean the Rivers Board?—Oh no, sir; I mean your board. Might I say at once, sir, that I think engineers ought to have some definite idea as to the amount of dilution allowed before overflow takes place. We have lately got into the habit of measuring these things by what we call "volumes," which is a very handy phrase, and practically now there is a concensus of opinion to overflow at six volumes, but it is an exceedingly indefinite standard. Let me illustrate. Supposing I had a town with a dry weather flow, domestic sewage, of 30 gallons per head, six volumes would mean that I would not overflow till I had 180 gallons per head going down to my sewage disposal works. Across the other side of the river or in the next county, I might have another town with the same population domestic sewage, in which the flow would be 20 gallons per head; six volumes of that would mean that the overflow would take place at 120 gallons. Well, as regards the pollutions it is the same in each case, for an individual in one town contributes just as much as the other, and the mere fact that you have a lot of leakage or a lot of waste water in the sewage should not alter the standard at which you can overflow it. I think that 120 would be getting as low as one ought to go; 150 I would not object to; 180 I think is going rather far, for there is a difficulty in making the sewers large, but I am rather inclined to the view that we had better err on the side of giving plenty. I certainly would not go below 120 gallons per head; I would like 150.

7542. One hundred and twenty gallons would mean about four times the dry-weather flow at 30 gallons a head?—At 30.

7543. The question would be whether the county authority, the Rivers Board, or whoever had jurisdiction in the county, would allow the overflow from four times the dry-weather flow to go into the river?—True; I think, as an engineer, I would take my chance. Of course, they have no powers of dictating; they have to prove offence, and I would never hesitate if I was in a difficulty to put in as low as 120. If I could get past your board I would take my chance.

7544. The Local Government Board determine it from other considerations, not from any arbitrary rule or what the view of the county may be——

7545. (*Professor Ramsay.*) Is it not the case that the first part of the flood is the dangerous one?—It is the dirty part, sir.

7546. You would take that into the filters?—I would take that up to three volumes in the filters.

7547. Would not that dispose of the whole of the dirty part?—Not quite, sir. My experience of storms which continue for some time is that the first rush is the worst; it continues dirty for an hour, perhaps, and after that it becomes dilute sewage—very dilute sewage.

7548. (*Sir Michael Foster.*) Dirty means putrescible?—Yes; I am speaking of organic impurity.

7549. (*Mr. Killick.*) Might I ask, have you ever had any difficulty or know anyone else having any difficulty with a Rivers Board with four times the volume?—I have been threatened, but nothing happened. I do not think that we as engineers—at least, I am speaking for myself—when I am advising a town what to do, I do not consider County Councils or Rivers Boards, or anybody else. I try to get at what is the reasonable and proper thing to do there, by supposing that I was the owner of the whole of the town and the whole of the interests in the rivers and the whole of the interests in the land; supposing I had a mind big enough to comprise all that, what would I as the father of these people do reasonably if I had every interest to consider? According to my present knowledge, I would overflow at 120 if I was in a difficulty, or 150 gallons per head otherwise.

7550. I simply ask as a member of perhaps the largest river board, as far as the work goes that has been accomplished, and I know of no instance where the rivers board has insisted on this question of dilution?—If I may express an opinion, I happen to know the board you refer to; I think that the board exercise an exceeding wise discretion in the matter. I do think, and I hold very strongly, and I hope I will have an opportunity of enlarging my views on the subject, that we should as sanitarians get the dry-weather sewage and a little of the rain thoroughly dealt with, and then, when we have got into the way of handling that with advantage and economy and efficiency, it is a very small matter what is left over to deal with; I am very strong upon that, sir.

7551. (*Chairman.*) I am not quite sure that I understood. I thought you said if you had a free hand you would only allow 80 gallons per head?—I have not made it clear, then. What I would do, I would treat 80 in what I call my sewage works, as sewage. Then after that I would deal with the difference between that and the 120 and 150 gallons through the storm water filters; anything beyond that I would overflow. I have a case in my mind where we did deliberately overflow at 100 gallons.

7552. (*Sir Michael Foster.*) At 100?—At 100, without any disadvantage to anybody. I will not mention the name.

7553. (*Mr. Power.*) Was that into a river?—Into a large river, sir.

7554. (*Sir Michael Foster.*) A very large river?—A very large river. The whole of the yard, roof, and street water went in, and we overflowed at 100 gallons. There I do not hesitate to say something goes out at the first rush of the storm that would be better kept in the sewers. It would be better, but nobody is hurt, and this is a practical question, you know, gentlemen. It would have been a very big thing to have taken, say, 150 down to the sewage works; it had to be all pumped, and the difficulty of lifting large quantities like that is very great in an emergency, and we thought the best solution was to do that, and it has worked for six or eight years without any disadvantage.

7555. (*Major-General Carey.*) Perhaps nobody has found it out?—Because nobody has had any occasion to complain.

7556. (*Sir Michael Foster.*) Have you any idea what the volume of your effluent was in regard to the volume in the river?—Oh, yes, sir; you are speaking now of the disposal works?

7556*. Yes, in this case?—There were 1,200 square miles behind it.

7557. (*Mr. Power.*) The destination of your effluent or sewage does then govern your procedure to a considerable extent?—Very largely. I have a very strong opinion upon that point, that our sole duty from the health point of view is to turn out an effluent that causes no nuisance or injury or annoyance in the river into which it goes. Fixed standards I hold in abhorrence.

7558. (*Major-General Carey.*) Was that with reference to the putrescibility of the effluent? The effluent may be putrescible; may not create any nuisance at the time of discharge in the river, but there may be secondary decomposition into the river, and the river may be as foul as the original sewage after a little time?—That would be wrong. That I would prevent. I hold that to be within my standard; it must not cause any injury or nuisance or annoyance in the river at any part of its course. In my view, when all our

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purification processes are done, we are dependent upon the rivers for the last touches.

7559. (*Mr. Killick.*) Still you do yourself formulate a standard, which is that it shall not be a nuisance?—Clearly; that is a question of fact.

7560. (*Colonel Harding.*) Have you been able to ascertain what degree of purification would avoid causing any nuisance?—I have not, sir; but it must vary with each case.

7561. (*Dr. Russell.*) Take the case of this river town. Was it used as a water supply?—Oh, no. That I hold to be one of the circumstances; if a town has the disadvantage of having below it another town drawing water from the river it has to put up with that, and work to a very high standard indeed; but if, on the other hand, there are no interests for miles on the river of any importance, I do think it is hard upon a town that it should be compelled to work to the very highest standard of purification.

7562. (*Mr. Killick.*) But you would take in all cases as the standard non-putrescibility?—Certainly, and it must be clear.

7563. (*Dr. Russell.*) Do you attach a definite idea to putrescibility? Is it tested by incubation?—Yes; if that is the proper test, I have no objection to it as long as it corresponds with the fact in nature.

7564. (*Mr. Killick.*) The standards that you are speaking against are the standards of the 1868 Commission?—No; I have no particular ones in my mind. This is my general view about standards. I fear it is impracticable, but it does appear to me to be common sense that if you have a standard of purity of grains per gallon or something of that sort for the effluent, that if it is sufficiently stringent to deal with difficult cases, where the volume of the effluent is large compared with the volume of the stream into which it is discharged, then it is unduly hindering to a town that has many hundred times the volume of water into which to discharge its effluent.

7565. (*Chairman.*) But may I just ask this, I did not hear quite what you said; would you say that all effluents, no matter what stream they went into, should be non-putrescible?—I think I would subscribe to that as a general proposition. There may be an exception or two. I am not speaking of tidal rivers.

7566. (*Sir Michael Foster.*) Is not what you mean that the effluent would be of such a character that it would not give rise to any putrescence in the stream into which it is discharged?—That is exactly what I have been trying to say.

7567. (*Mr. Killick.*) You so far incline to the view of a standard?—That no injury or damage or annoyance be caused in the river by it.

7568. (*Colonel Harding.*) It is not a question of the putrescibility of an effluent, but the putrescibility of an effluent after admixture with the river?—Might I mention when I was at Chiswick we only had chemical precipitation. There is a very large volume of the Thames which is tidal, twice a day, and of course it was not possible to get an effluent of any great degree of organic purity. We did very well, but we did not work to what are now known as the modern standards. The Thames Conservancy summoned us for polluting the river, and undoubtedly we polluted the river; there was no question of it; but no one could see the pollution or smell it, or in any way distinguish it. In fact, when the summons came I went the next day and got a boat and took half a dozen Winchester quarts with me, and I floated from the effluent, from where it was discharged, half a dozen corks, and they went in various ways, and about 50 yards away from the outfall I dipped my bottles one after the other into the river. Then I had an odd one, and I went right out into midstream, away from any possibility of my effluent affecting it, and I labelled them a, b, c, d, e, f, g. I sent them to an analytical chemist, and asked him to tell me which were the ones which were sewage polluted and which the river water, and he could not. I thought it was very hard that I should be pulled up and prosecuted for polluting the river when you could not see it, or smell it, and the chemist could not find it out.

7569. (*Dr Russell.*) Still you posit this condition that the water would not be drunk?—Oh, clearly.

7570. (*Colonel Harding.*) But, after all, is not this the way in which the present serious condition of rivers has arisen, that at first authorities have polluted the stream in small quantities relatively to the flow. No evil has been noticed; others have done it, and finally a condition of things has arisen which has been absolutely intolerable?—True, sir, then they have to raise their standard.

7571. (*Mr. Killick.*) There is another difficulty. If you are judging the pollution not of the effluent, but of the effluent plus the stream into which it flows, and your stream, as all streams are, is constantly varying, neither the engineer in charge nor the inspecting authority nor anybody else would know where they are?—True, Sir, except in this respect—that immediately what they are doing at any particular sewage works pollutes the river visibly, prosecute them; but in the meantime I do not understand why they should be made to work up to a standard at great expense when the effluent they are then discharging does no harm to anybody. Let me illustrate. I was down in the West of England upon a pollution case which was a trivial matter, very trivial. I was speaking to the chemist, and he said, "Oh, yes, we are polluting the river here, but the enormous volume makes it very dilute." Some boys were bathing from the banks. One of them made water in the stream. Well, if that had been analysed it would have polluted the river, but who in the world would think of prosecuting; and that is simply an illustration in that individual case of what the other place was doing on a larger scale, but in neither case that I could distinguish was there any annoyance or visible pollution.

7572. There is another matter you have to consider if you want to enforce the Rivers Pollution Act; it is tolerably clear that you will have to deal with the whole of the water-course. If you make one standard for one part of the water-course and one standard for another you have very little chance of getting either standard carried out?—Of course if that is so that is an answer to me; but it does seem to me that the Rivers Pollution Act does not set up a standard, but the sole test is, does that particular place on that particular day when that sample was taken produce pollution?

7573. If that effluent were proved to the satisfaction of the court that it was putrescible then you have the damage done at that particular place at that particular time?—Well, that I think is hard in some cases, because although the effluent might be putrescible by itself like that which the boy passed into the river, if it did not as a fact in its putrescence cause any evil in the river, I think it is very hard lines that that authority should be fined.

7574. (*Professor Ramsay.*) But is it not merely a question of distinction? It appears to me that Mr. Strachan gives us all we want when he says that the effluent shall not be putrescible?—In the river, sir?

(*Mr. Killick.*) That is the effluent plus the river?

(*Professor Ramsay.*) Yes, but if the effluent itself is not putrescible the effluent plus the river would not be.

(*Mr. Killick.*) The effluent itself might be putrescible and plus the river it might not be putrescible.

7575. (*Colonel Harding.*) Perhaps you might allow me to put it in this way—that all Mr. Strachan would do would be to take steps to prevent putrescibility in the mixture?—Clearly.

(*Sir Michael Foster.*) To prevent putrescibility being obvious.

(*Mr. Killick.*) In the mixture.

(*Sir Michael Foster.*) In the mixture it might be just up to the margin, but if it was not obvious Mr. Strachan would pass it, and then the next very small addition might bring it beyond the obvious level.

(*Mr. Killick.*) A change of the stream itself from the pollution of an authority or an individual.

7576. (*Colonel Harding.*) The difficulty I see in this case is that with the development of populations the evil would gradually arise which has arisen, namely, the intolerable condition of our rivers by the steady and gradual addition of dilutions from various sources which individually were not serious, but collectively bring about an intolerable condition of things. If it should be shown to be practicable to so far purify sewage as to turn out an effluent which in itself was non-putrescible, surely that would be a safer condition of things to promote than the other, would it not?—Undoubtedly, it all depends on the expense of it; if it could be done at a reasonable cost.

7577. Yes, and the whole thing turns upon this—is it practicable by any known system of sewage treatment to turn out effluents which in themselves are not putrescible; that is to say, if they run in a course and are not mixed with other water would they in the course of their flow along such course and in such a stream produce any nuisance?—If that can be done systematically and regularly at a reasonable expense then I think it is a highly desirable end to attain.

7578. Then have you not in the course of your experience of certain examples of land treatment met with quite a considerable number of effluents that would come within that limit?—I cannot answer you, Sir. I can answer to this extent, that I have seen plenty of farms where the effluent has not been putrescible in the river, but whether it would itself have been I could not say for certain, I do not know.

7579. But you have, I think, watched some of the biological experiments?—No.

7580. I thought you told us just now that you had watched certain of them only in sewage treatment?—Yes.

7581. You have probably seen analyses of some of these filtrates?—Yes.

7582. And probably seen statements of the putrescibility or otherwise of these effluents?—Yes

7583 Have you not known cases where an effluent has turned out non-putrescible?—I can only speak from what I have been told I have been told it is non-putrescible, but whether it is a fact or not I cannot say. I think it very hard lines upon a town, the name of which I will not mention, if it were pu tto an expense of, say, £500 a year to turn out an effluent which is absolutely non-putrescible when the effluent which is at present being turned out there causes no injury to anyone, and is sufficiently good to be turned into the river.

7584. As this is an important point I would ask your permission, Mr. Chairman, to press this. (*To Witness.*) Have you any knowledge of Leeds?—Yes, what I have read.

7585. You have not seen an analysis of the river there?—Yes.

7586. You know its abominable condition?—I know it comes out very bad.

7587. How would you deal with the Leeds authority turning their sewage into that stream; would you consider it sufficient to have mere chemical precipitation and a purification of 50 per cent; would you consider it likely that so abominable a stream would be polluted by an effluent only purified to that extent?—Oh no, sir, no; what I would do in a case of that kind is I would say to Leeds that you must deal with your sewage so as to send it out clear, so that when that quantity of water coming down clean that now comes down to you dirty was mixed to your effluents as far as we can tell it would not pollute.

7588. Apparently you have a standard?—Simply the water and the river.

7589. A standard of purification varying with the stream?—No, sir.

7590. If the standard is to be that the mixture with the stream shall not cause pollution, then with an already polluted stream according to your plan, you would not ask the Leeds people to do anything?—I have not made it clear. Supposing there were 100 million gallons coming down the river above Leeds. Assuming that Leeds sends in ten million gallons of effluent a day—I do not know the figures—then until I have got my river clean above by the operation of what I would do I would judge Leeds by this standard. I would take their effluent as they send it in. I would mix it with ten times the quantity of water, that is, to one-tenth of the hundred millions coming down, and then judge as to whether they were doing their duty or not. I recognise the difficulty that you put to me.

(*Major-General Carey.*) If the river was very polluted, as it is at Leeds, you would not find out whether the corporations were doing their duty, because the mixture would never show it to you. The river is probably more polluted than the effluent.

7591. (*Colonel Harding.*) The river would probably be found to be more polluted than the very indifferent effluent which they are now turning out at Leeds by lime precipitation, which only gives a purification of 50 per cent. Then in such a case you would not ask Leeds to do anything?—Oh yes, sir, I have not made it clear yet. What I would do would be this: I would judge what quantity of water was coming into the river above Leeds.

7592. You mean the volume of the river passing Leeds?—The volume of the river I would treat as clean water—no pollution. I would take a sample of the Leeds effluent, mix it in the proportion with clean water as its own volume bears to the flow of the stream, and then judge them by that standard until I had got the river clean, and then gradually apply a stricter standard all the way along.

7593. (*Major-General Carey.*) But that is a standard; of course you are laying down a standard?—I wish to say that my standard is what will the river stand—a clean river stand. I don't mean a polluted river I have no sympathy with those people who neglect their duties.

7594. (*Colonel Harding.*) You have a standard; it is to be an effluent which is non-putrescible when mixed with a given volume of clean water?—That is so, sir; I think you must have a standard. What I wish to say is, having a definite standard of so many grains of this and that for all circumstances and conditions seems to me to be wrong.

7595. (*Mr. Killick.*) But you are landed in this practical difficulty: you are assuming that a standard varies with the volume; you must either begin with the upper places on the stream and make them purify first, and so on all the way down, or you must first ask for one standard, and a little later for another?—Well, my standard is a variable one; it is bound to be a variable one.

7596. And the works will have to be variable?—Certainly. I think a town is bound as it increases to do more and more with its sewage.

7597. (*Colonel Harding.*) Your standard would not vary with the condition of the river, but with the volume of the river?—Yes, except that if by the condition of the river you mean its previous pollution that I exclude from my standard altogether—I except that.

7598. (*Dr. Russell*) You always posit the condition that it shall not be drunk—that it is not potable water?—Oh yes.

7599. (*Major-General Carey.*) In all small streams where the effluent was equal or more in volume than the stream, you would insist upon a much higher standard of purification?—Certainly; you are bound to, I think. Putting it broadly, a town is entitled to its physical advantage of having a big river going past it. If a town has a small river, like Birmingham, and some of the towns on the top of the watersheds, that is their disadvantage, and they have to work up to it.

7600. (*Chairman.*) Take a river just after its start. It is probably very small; well, you would not allow it in the first instance to be polluted at all?—Oh well, sir, yes. I hold that all effluents are polluting strictly speaking. I may be utterly wrong, but I hold that, and I would make that town highest up nearest the ridge work to this standard, that when its effluent was turned into the river there should be no nuisance or inconvenience or injury or putrescence in the river after it was turned in.

7601. Well, then, you presumably put that particular town to great expense, because we will assume that the river is small soon after its start, and, therefore, it could only render an effluent harmless to a very slight extent, if at all?—Exactly.

7602. Therefore you would consider it right that that particular town should go to great expense to avoid pollution?—Certainly, otherwise the alternative seems to me that you have to allow the river to be polluted. My standard is that there must be no pollution as I define it.

7603. (*Mr. Killick.*) And the smaller the stream the higher the standard?—Certainly. It seems to me common sense. I mean broadly, we turn crude sewage into the sea with a properly chosen outfall, without inconvenience. I could name two or three places in tidal rivers. We allow chemical precipitation, and that not only in London and Chiswick, but in inland towns on big rivers. Whatever the rules may be, they are not worked up to, but no inconvenience ensues. In towns higher up, where the quantity of water in a river is smaller, there the people must

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work to the higher standards. I think that should be recognised.

7604. (*Major-General Carey.*) In a case like Plymouth you are not allowed to turn the sewage into the Sound without treating it, are you?—Certainly.

7605. No treatment whatever?—None.

7606. (*Sir Michael Foster.*) Has no inconvenience arisen?—I am only carrying out the scheme, sir.

7607. (*Major-General Carey.*) Was there not some proposal for treating it before Mr. Mansergh was consulted?—Yes, that was when it was proposed to be discharged close in shore. They proposed to put permanganate into it, and then turn the whole mixture into the sea. That was knocked on the head when we undertook to take it out 500 or 600 yards to a great depth.

7608. It depends very much where the outfall is to be; whether you can afford not to treat sewage; or, in fact, on the position of the outfall with respect to the town which it serves?—I agree the outfall must be well chosen when crude sewage is discharged.

7609. In the case of watering places, if you were to discharge crude sewage into the sea, you might have the crude sewage floating up and down in front of the beach. Untreated sewage would become a frightful nuisance unless it were specially provided against in some way?—I agree, but I would like to say that of all the views I hold on sewage I hold none more strongly than this, that if you can get a well-chosen outfall into the sea it is out and away the best way of disposing of sewage.

7610. Without treatment?—Without treatment.

7611. But it depends on the local conditions of the place?—Yes, a well chosen outfall; Torquay seems to me to be an excellent case. They have had theirs in operation now for 40 years. They discharge the sewage at all states of the tide, nobody ever sees it in any shape or form.

7612. Owing to the position of the outfall?—Yes.

7613. You go to Falmouth, where they have a land-locked harbour, and if you discharge crude sewage into the harbour, it would probably never leave it?—Oh, of course.

7614. (*Professor Ramsay.*) It is very difficult indeed to draw the line. Take the Clyde, which is becoming uninhabitable along the shores simply because the sewage is discharged from each house into the river?—Yes, then in that case something more has to be done. I have done a lot of sea outfalls, and if the Commission care I will mention what was done at each. We have done a great many lately.

7615. (*Chairman.*) If we go on to another question, have you had any experience about choking in artificial filters?—Simply what I have read and observed. I think they do choke if you do not have sedimentation; but as far as I can judge, if you have got sufficient tank capacity, say, 24 hours or more for your sewage, then I think that you may depend upon a fairly constant capacity in the filters underneath if it is domestic sewage only.

7616. You have had no prolonged personal experience?—No, only what I have observed.

7617. As regards land treatment, do you consider that there ought to be some preliminary treatment of sewage before it is turned over land?—Yes, I think it is well to take out the grosser solids; I think that is very helpful.

7618. Either by settling tanks or by screening, I suppose?—Well, screens, I think, are scarcely sufficient, if by screens you mean iron screens, they are scarcely sufficient. I do now, in my own practice, put the sewage into an upward flow tank at the bottom, and it has to pass through two feet of clinker and overflow at the top. I clean them out every week at the bottom; it is very helpful.

7619. (*Colonel Harding.*) In such cases is the clinker carried by a false bottom?—Yes.

7620. A grating?—A grating, as a matter of fact, girders across and straight bricks.

7621. (*Major-General Carey.*) You are referring to large areas of sewage disposal when you say you would screen the sewage beforehand. That is the only treatment you would have beforehand. You would have to have a very large area of land for sewage disposal?—Certainly.

7622. Taking, say, 2,000 or 3,000 gallons to the acre?—Yes.

7623. (*Chairman.*) Do you consider that all kinds of land will purify sewage?—As far as I know, everything short of rock.

7624. You do not think there is any clay so hard that the sewage would flow over it without getting clogged?—I have never met it. I have never met with clay on the surface, there is always some soil, always some.

7625. What would you say was the greatest amount of gallons that an acre of best land would deal with?—I cannot tell you what it would take; I will tell you what I put on it myself. I do not know what the limit might be. I would not put upon what I call stiff harsh lands more than 3,000 gallons to the acre, and upon the very best lands that we have got I know nothing which would justify me in putting on more than 30,000; but land may be capable of dealing with more. I merely know of no experience which would justify me in doing it.

7626. And do you find that frost or very cold weather affects the purification on land?—I have not experienced that. I daresay if the effluent was analysed, and I am speaking merely as an engineer, it may be that it is not quite so good in the winter as it is in the summer; but then, of course, my standard in the river comes in again. The river is not likely to kick up at having the effluent in the winter so much as it is in the summer. The thing rights itself. I would like to say that I look upon land treatment as quite out and out the best thing to do with inland sewage if you can have plenty of land.

7627. You do not think that it deteriorates the land?—I have no experience that it does.

7628. Assuming that proper care is taken?—I have no experience that it does. I will take Croydon, for instance. Of course, Croydon has been in operation a long time, and there are some things to be said about it; but, broadly speaking, I think the Beddington farm all through has done well. I make it a rule when I go on to a sewage farm which has been heavily dosed with sewage to dig into it to see what it is like. I have never found discolouration more than two inches or two and a half inches down; underneath it is clean and natural, as it was the first day. It may not be so chemically, but it looks like it.

7629. (*Professor Ramsay.*) Would you be willing to insist on a minimum acreage of land to purify sewage?—Well, take clay, for instance. I would not, under any circumstances, as far as I know at present, allow anyone to put more sewage on than 3,000 gallons per acre.

7630. (*Major-General Carey.*) Whether previously treated or not?—Yes, and I would insist then on passing through an upward screen tank or sedimentation tanks. It may be too low a standard; that is what I would do myself, and I certainly know nothing that would justify me in putting 30,000 gallons per acre.

7631. (*Professor Ramsay.*) That is the maximum?—That is the maximum on the very best land that we have got. It may be that land will do more than we think; but I know of no case. I may say that for years I have been looking out for the place that is dealing with 2,000 persons to an acre. I have visited, I think, all the places that I have heard of, and it does not exist that I can find, and I have come to the conclusion that it never did exist.

7632. (*Chairman.*) Should I be right in thinking, I have rather gathered it from the general tenor of your evidence, that you are of opinion that every great community should be left as free as possible to deal with their own difficulties?—I think they should be given for some years a very free hand. Might I say my mind on that subject?

7633. Yes, do?—I have been concerned with most of the big towns whose problems with sewage are unsolved to day, and I do think it is very desirable that they should be allowed money to carry out whatever they can get responsible men to advise them is likely to lead to success, without being hampered by conditions that they shall make a complete solution of their problem. May I mention Manchester. I have no brief for Manchester, I know nothing of its present difficulties; it is many years since I was engaged for them; I only refer to it because it illustrates my point. The experts who reported, fixed the dry weather flow at 25 million gallons per day, and their scheme, I think, was for 30,000,000. Well, to an engineer, it is a big operation

to deal with, 30,000,000 gallons of liquid. It requires considerable manipulative skill on the part of the men, however carefully the engineer may design the works. Now, as to Manchester, I merely take it as an illustration. I would allow Manchester, if I had my way, as much money as it required on loan for a reasonable number of years, to deal with, say, 60,000,000 gallons of the whole quantity every day that comes down. I would tell them frankly that they need not bother about the balance for the moment, and then when they have got their works into operation for dealing with 60,000,000, I think Manchester would, being a big progressive town, be desirous of having its rivers clean and would tackle the other. I am sure that if that was done they would enter into this problem with a better heart. Now in the experts' report at Manchester they gave instances of where the sewage came down mixed with rain at the rate of 180,000,000 and 190,000,000 gallons per day. Well, that is the dry weather flow of the Thames at Teddington, and while, as an engineer, I am not going to say that I cannot design works that will deal with it, at the same time it is a very big problem, for what it means is this—that you must have your works designed in such a way that they will deal with a minimum flow at the rate of 10,000,000 gallons, and then, with scarcely any warning,, they are to be equally competent to deal with 180,000,000 gallons. Well, I suppose it is possible, but I should not like to run sewage on to works at more than 200 feet a minute velocity, and 180,000,000 gallons a day is 20,000 cubic feet a minute. That would require a channel 5 feet by 20 feet to carry it. To have that suddenly thrust upon you at any moment of the night, to be upon a war footing, so to speak, any minute of the day, so that when it came down you could deal with it successfully, does seem to me to be an enormous task, and I think those towns that have these very big problems should be given less to do at first. Do away with 90 or 95 per cent. of the nuisance; when they have done that let them deal with the other. I daresay that is rank heresy, but it does seem to me what I would do at present.

7634. (*Professor Ramsay.*) But you rather suggest that the authorities at Manchester should deal imperfectly with practically the whole of their sewage rather than deal perfectly with a small quantity?—I would prefer that they should deal, what I would call perfectly, to use your word, though it does not quite express my meaning; that they should deal properly with the whole of the dry weather sewage systematically. I would give them that chance first, and then when they had solved that problem I would call upon them to deal with the other, which in bulk, though very large, is not relatively so enormous.

7635. A very opposite policy has been pursued; they simply excluded all their crude sewage to see what they could make of it, letting the main bulk of it escape?—That I think is wrong. Of course, so long as they were experimenting that was a justifiable policy, but supposing that Manchester could find men, in fact, they have found men of standing to recommend to them a definite scheme, who say that in their view that scheme will deal with the sewage, then if I had my way I would say to Manchester take all the money you want for that, we will be content if you deal with the dry weather sewage and one volume extra to allow for the first rush of the water. We will be content if you tackle 60,000,000 gallons a day without your putting down works to deal, on a war footing, with 180,000,000 that must be dealt with later, for the present we excuse you dealing with the difference between that and the 180,000,000 gallons. And I am quite sure that Manchester, Leeds, Sheffield, Bradford, all those big towns would tackle their problem with a better heart if they were given something that was more easily got at than the whole problem.

7636. (*Major-General Carey.*) Take Manchester with its 25,000,000 gallons, who has asked them to treat 180,000,000?—I do not know that anyone has, but the problem that the engineers got was to deal with that quantity. What I had in my mind was this: that if I brought forward a scheme to deal with two volumes I might get it through, but I would hardly expect it. I think I would get it through Parliament, but I doubt if I would get it through the Local Government Board.

7637. (*Colonel Harding.*) Is there a Local Government Board standard now requiring a certain number of dilutions to be dealt with by the authorities?—I do not know, Sir. I know there is an unwritten practice of six volumes.

7638. Which you think would be quite impracticable for authorities?—I do not go so far as to say it is impracticable; it is too big a problem for them to tackle at once.

7639. Then in allowing them to deal with two dilutions as you suggest you would not keep back from them this knowledge that later on they would be required to do more?—Certainly not.

7640. You consider that that is essential?—Absolutely, but I think they have got practically an unsolved problem.

7641. Then, briefly, your view is this—that you think it would meet every reasonable case if any authority were to deal with four times its normal flow, but at first you would not ask them to deal with more than twice the normal flow?—Only in the case of those big manufacturing towns, not small ones.

7642. Where you would go to six?—I wish to limit what I have said to those big manufacturing ttowns.

7643. But if you were only treating twice your dry weather flow that means that everything over twice has to go into the river?—I agree.

7644. But no Rivers Board would consent to that?—I would let the Rivers Board take their action.

7645. The difficulty now is that nearly the whole of it goes into the river untreated. You merely look on that as a step towards something better?—Quite; I do not know the Rivers Board, but they are practical men, and would act reasonably if Manchester said: "Now, gentlemen, we are going to tackle 60,000,000."

7646. (*Major-General Carey.*) "We are going to tackle twice our dry weather flow," never mind the 60,000,000?—"Twice our dry weather flow. When we have dealt with that we will tackle the other. If you choose in the meantime to prosecute us we will stand our chance with the magistrate." But they cannot get the money. I know the case of Salford. Salford could not get the money, and I look with exceeding approbation on the action of Parliament that gave Salford last year power to raise £150,000 without a condition as to land treatment or anything else. Salford will be brought to book by the Rivers Board if it does not do its duty.

7647. (*Chairman.*) You approve of the action of Parliament in that case?—Thoroughly. I supported Salford wholly; it seemed to me commonsense.

7648. Would you like to see a general law under which each town as big as Salford could get a loan which should leave this without conditions?—No, I do not go quite that far. I would rather say if the Local Government Board, for instance, would plainly recognise that this is a thing to be done in the cases of these big towns (and bother the thing whether it is consistent with another town which has different circumstances). I think that would be sufficient. I think the Local Government Board might very fairly say "We will accept that as a first instalment.

7649. (*Major-General Carey.*) Do you not think it would be very difficult indeed to get a place after it had carried out its first instalment to go on with its second instalment?—I think not. I think when the people realised what an improvement came to their rivers when they had dealt with 90 or 95 per cent. of the pollution they would tackle the other. When they have learned to manipulate that portion of their sewage they will appreciate what it means to be clean and tackle their duty in a proper manner. That is my view; at any rate, the law is strong enough to make them.

7650. (*Sir Michael Foster.*) You were about to tell us something about your experience about the outfall into the sea?—I have had just yesterday a very instrnctive example of a sea outfall, for it happens that the Harbour Board in the town that I am referring to are carrying out pier works within 500 yards of the sea outfall, and this curious thing came up. The sewage is discharged crude at all states of the tide, and during calm weather the pier people when digging out the foundations have never experienced any inconvenience from the sewage, but after a storm when they go back, because they cannot work in the storm, they find the bottom of their trench filled with sewage débris. I think that is very instructive in this respect: it shows conclusively to my mind, knowing the circumstances, that about 200 yards out or so from the outfall there

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does in calm weather gather a large bank of sewage mud under the water. It causes no nuisance, there is no sign whatever of it on the water, but during storms it is moved away, because it is old sewage and not fresh sewage that comes into these trenches. Therefore, it opened my eyes to what I had not realised before, namely, that within a very few hundred yards of the shore an outfall that does not give any signs of surface pollution or any signs whatever of pollution by putrescence may be causing a deposit upon the bed of the sea. It inclines me more than ever I have been before to get my sea outfalls well out into strong currents. I have done Exmouth lately.

7651. (*Major-General Carey.*) And discharge on the ebb tide?—I am going to mention them now. At Southend it is partly sea and partly tidal. We have large tanks, and we store the sewage up; that is the dry weather sewage; the rain we cannot. We store the sewage up for eight hours, and let it go on the top of the tide, and two hours before low water it is shut off, so that the tide has two hours going out to carry it awa y. There is no inconvenience felt there. At Sidmouth practically the same thing is done, only owing to some very curious currents that are there it is only let out for one hour, it is stored for 11. At Shoebury practically the same thing is done; we let it go on the falling tide. At Worthing there was no chance owing to the levels of getting a storage tank that would discharge by gravitation, so there we built the tanks at a high level. We pump the sewage up, and discharge it upon the tides that carry it away. It does not happen to be high tide or low tide, it is between the two tides owing to the curious currents there. The thing it seems to me in sewage outfalls is to get the sewage into those currents that would carry it away from the town.

7652. (*Sir Michael Foster.*) Do these currents mean distribution or simply transference?—Transference.

7653. And deposited elsewhere?—I suppose that must happen after what I have explained to you about that other town, but in all the cases that I have mentioned there is no visible evidence of this deposit, and I take it that as long as that is so we need not worry whether it is there or not if nobody is hurt.

7654. (*Mr. Power.*) The floats gave no indication of such a bank forming?—None whatever, sir.

7655. (*Professor Ramsay.*) Is there no special kind of vegetation, no special kind of seaweed?—None that we found; it never gave evidence of its presence until this pier came and the storm moved it.

7656. (*Sir Michael Foster.*) That was old sewage, that was moved?—Unmistakeably old sewage as opposed to fresh sewage.

7657. (*Major-General Carey.*) And that applies to the open sea out-fall not to tidal water?—Oh, no, that is the sea.

7658. Was this an estuary?—It is the channel.

7659. It is the open sea?—It is the open sea. Now at Aberdeen they have just got a scheme through Parliament two years ago for discharging the whole of the crude sewage upon the nose of land that is to be south of the salmon river. One naturally inquired what the effect would be upon the salmon. It is a matter of opinion; it must be until the thing is tried; but there was a consensus of opinion on the part of all the experts on salmon that it would not prevent the salmon coming that way going through it, and up the river. I was rather astonished at it.

7660. (*Major-General Carey.*) They have got evidence directly contrary to that at Exeter?—I heard all sorts of funny things at times, that is what was said there; the salmon now go through all the sewage of Aberdeen.

7661. (*Professor Ramsay.*) You have had experience of the upward screening of sewage, have you?—Yes.

7662. Before broad irrigation takes place?—Yes.

7663. What is your opinion of that?—I think very highly of it.

7664. It works well?—I think it is more than mechanical; I only judge as an engineer, I have not analysed it, but it seems to me the stuff comes out a great deal cleaner than mere mechanical straining, and the small quantity of sludge relatively that you get left is very striking.

7665. It is easily removed is it not?—If you design your works properly quite easily removed.

7666. And does not make a nuisance?—Well, I always place it upon constructed filters, so that it parts with the water readily, and in two or three days barrow it away at once. But as it is the old open air sludge method I always take care to put it in a place where it will not be offensive.

7667. Have you seen the Nuneaton system?—Yes.

7668. Are the Cosham precipitating tanks used there?—There is a special tank there.

7669. Can you give us any idea as to how it works?—I do not tie myself to that particular tank, but I do hold that he tank that they have at Nuneaton—that deep tank with the upward flow—I think that is the preferable form of sedimentation tank. As a matter of fact they are going to use them wholly at Nuneaton. I was advising Nuneaton. I have another scheme in which I wanted to have sedimentation before the contact beds, and I have put down one of those tanks about 20 feet deep with a conical bottom. The sewage will be taken in at the bottom and it has to rise through itself. That tank will hold a day's flow. I think I will get the true septic condition; I think further I have all the advantage of the falling sludge straining the rising suspended matters. In addition I have an easy means of emptying the sludge at the bottom simply by turning the valve owing to the pressure of the water on the top.

7670. Do you intend to empty the sludge?—When necessary.

7671. If it is to act as a septic tank the sludge surely should not be emptied?—Well, it would come to be a necessity, because if I understand the septic tank it is filling up one sixth a year at Exeter that is my observation. Its capacity in two years has fallen from 43,000 to 31,000 gallons. It is only a question of so many years before it chokes up.

7672. It is a question of how many years. Some people think it very much slower than that, but still you would propose to have appliances to discharge your deposit if necessary?—I think the deposit would be small, but I would have means to discharge it.

7673. What volume does your tank hold; is it being constructed?—It is being constructed. The one I have in my mind would hold a little over a day's flow.

7674. What does that amount to there?—It is only a small place—about 34,000 gallons. I may mention that at Nuneaton the scheme that was put forward there was for open septic tanks. The surveyor very properly in my judgment has determined to put in these deep tanks instead of the open septic tanks. I think he will get a better result than he would with shallow tanks.

7675. Is the deep tank the Cosham one?—I do not know. I think the Cosham one is another tank with a lot of concentric appliances; if so I do not think much about that.

7676. Is it very costly to make such a tank in comparison with making an ordinary horizontal tank?—It is more expensive, but if the ground in which the tank has to be made is like clay or rock then they are not very expensive, but they are more expensive of course than shallow tanks. It seems to me if you have to roof them in, the roof is very much smaller, and there is the advantage of their efficiency. I judge that their efficiency will be ahead of any form of septic tank that I have seen.

7677. (*Major-General Carey.*) How do you arrange your storm overflow for any desired number of dilutions. If your storm overflow is designed we will say to take over five dilutions, and the weir is fixed and the population increases, of course that proportion is lost at once?—Not quite. What I do with all my storm overflows is this: I put them in at the level of the soffit of the sewer. I never allow overflow until my sewer is full. The way that I regulate it is this; if I am doing a pumping scheme I merely put in pumps that would deliver six or eight volumes, or whatever I chose. Then the other has got to go. If on the other hand it is a gravitation scheme then I throttle the outlet so that it does not pass more than I want to the farm. I entirely disagree with the practice which puts the overflow half way up a sewer, or two-thirds up a sewer. I think this will show that my overflows would not need altering, I would simply augment or enlarge my pumps as the population grew.

7678. I am not talking of a pumping scheme, but an ordinary gravitation scheme, with a certain number of overflows on to a line of sewers?—Or in the case of a gravitation scheme I would throttle my inlet to my

sewage works, so that it would not pass more than the required quantity.

7679. The overflows I mean are on the line of sewers a long way before you come to the sewage works. The ordinary overflows which are discharging into the rivers when the sewage is diluted by five times its volume with storm water?—As an engineer I do not know how to put an overflow on a line of sewer that will automatically discharge a given quantity of water. If you have an overflow above the soffit everything will run out of it when it is running full if there is no opening at the end. If, on the other hand, you put your overflow down at the end then it overflows exactly when you get the outside capacity up to that point, and the way I regulate mine is to throttle my outlet, and what cannot be got through the outlet is bound to overflow.

7680. That does not express any distinct proportion, does it, of the number of dilutions—simply throttle the outlet, everything else goes?—Supposing I throttle my outlet to pass six dilutions, then everything else overflows. I do not know any other way of doing it. I always take care at my sewage works to have my principal overflow fixed. I use intermediate overflows merely for relief when the sewers get under pressure.

7681. Do you take the maximum flow, say five dilutions, or the mean flow?—The mean; and of course if it happens to come at the middle of the day when the sewage is running foul, no doubt the overflow is a little fouler than it will be in the middle of the night.

7682. (*Professor Ramsay.*) What is the depth of your tank—of the one you propose to make?—I think it is 24ft., sir, to the bottom of the cone. There is a very fine example of that tank at Kettering—a very large tank—and the surveyor has been for some weeks passing through that tank its proportion of the daily flow to see its effect.

7683. And is it a masonry tank?—Brick.

7684. (*Colonel Harding.*) You have given certain attention to the biological method of treatment, but you told us you did not give special personal attention to that section of the work, and therefore I do not propose to ask you any questions upon that. You have made this statement that you think continuous is better than intermittent filtration, and you have approved of the septic tank?—Yes.

7685. But I take it that you have not given any particular attention to this work, and therefore it may not be necessary for me to press you for the grounds of your views?—I can only speak as an engineer—from the chemist's or bacteriological point of view my opinion is worth nothing.

7686. I will confine myself to the engineering features. You say it is desirable to withdraw the suspended solids from sewage, whether you are to treat it on land or by artificial filters. Do you think that it is necessary where you are going to put the sewage on land, not only to withdraw those solids, but to withdraw them in such a way as that there will be septic action, or do you only propose a septic tank where the second treatment is to be artificial filtration?—I think I would hesitate to have septic action without contact beds or some beds to follow it, because of the smell, but what I understand is that it would be helpful—the land would be helped if septic action were set up.

7687. You have not had any experience of treating septic effluent on land?—No.

7688. But you foresee that there might be a nuisance in connection with such treatment?—All the effluents from the septic tanks or tanks in which putrescence has occurred have always smelt; that I have found.

7689. Then where sewage is going to be treated on land you would have the capacity of these upward filtration tanks or separation tanks so small that septic action would not have time to arise?—Substantially they are so.

7690. The matters settled out would have been removed before septic action arose?—Substantially so.

7691. Where there is going to be artificial filtration you would have the capacity of these tanks sufficiently large to permit of septic action arising?—We are speaking of different forms of upward flow tanks—I would do away with the upward flow screen tank, and I would put in upward flow septic tanks of this capacity. I distinguish between the two.

7692. What is the distinction?—At Coventry it enters the tanks, passes through the false bottom, and up.

7693. It does in the other case too?—In the other case there is no false bottom and no filtering material in it.

7694. In the septic tank, which is to precede artificial filtration there is no surface screen?—None whatever.

7695. It is a mere septic tank?—A different form of septic tank.

7696. A mere natural sedimentation which is permitted to develop septic conditions?—That is so.

7697. Where you were going to put sewage on land you put it through a screen?—Yes.

7698. And remove the stuff immediately afterwards to prevent septic conditions arising?—Yes.

7699. You have not any experience of a septic tank covered by such a screen as you have referred to at all?—No, I take it the screen would not be necessary in the septic tank.

7700. But it would form a sort of roof, which you thought would be useful?—The screen is at the bottom.

7701. (*Professor Ramsay.*) The screen would be at the top?—The screen is a foot or so below the surface of the water.

7702. It has a certain depth of coke or something of that kind carried on a false bottom?—On a false bottom.

7703. If you have an adequate depth below that, so as to store the solids there down, and give them time to develop septic conditions, you have a septic tank with a screen roof?—I have not contemplated making such a thing before.

7704. I rather gather that is what you suggested?—No.

7705. Do you see any objection to that beyond the question of cost?—Cost. I do not know how a septic tank effluent would act if it had to go through this stuff; it would probably improve it. I do not know.

7706. The probability that it would throw down more of the suspended solids than it now does?—Yes, probably.

7707. Your reason for providing a roof on the septic tank was that to prevent nuisance?—I do not know, I think it is better covered up; that is all.

7708. Why?—Because I imagine at times it might be offensive.

7709. How would the roof prevent it being offensive?—By keeping the smell in.

7710. There could not be any permanent storage of malodorous gases?—They escape when you burn them.

7711. The roof to be effective must act as a store of malodorous gas?—Let it escape in the air. It is easily burned from what I have seen at Exeter.

7712. But if the gases which are produced and which are combustible are merely marsh gas and nitrogen and hydrogen they are not malodorous, are they?—My general knowledge says not, but I imagine that the septic tank effluent has a bad smell at times.

7713. That is a point about which I will not question you, but this engineering point is one upon which I think you can be very helpful to us. You expressed the opinion that the choking of filter beds is not necessarily fatal to your system of sewage treatment?—Yes.

7714. You foresee that sooner or later contact beds will probably choke up?—May—I prefer may.

7715. But assume that they do ultimately choke up, you say that the material may be renewed at a cost which is not prohibitive?—Yes.

7716. Assuming that the material is coke, what would be about its value per cubic yard?—6s. or 8s. put in.

7717. Take 6s. per cubic yard?—Yes.

7718. Well, what cost would that represent per acre?—About £1,500.

7719. Per acre, at 6s. per cubic yard; I have reckoned it out £2,178 per acre?—What depth, sir?

7720. 1½ yards, which is the usual depth for such tanks?—That would be so.

7721. You think that an expenditure of £2,000 an acre would not be prohibitive provided it did not arise too frequently?—Yes. Might I just mention the case on which I base that opinion, because I have the facts at Exeter. They have been working for 3½ years on 31,380 gallons a day. During that time those contact beds have dealt with 40,000,000 gallons of dry weather sewage, excluding rain. Now, they have 670 cubic yards of filtering materials in those beds. Supposing they dealt with it by what I suppose would be the alternative, namely, a chemical process. I do not know of any other alternative, and that is what I base my estimate on. Then the chemicals would have cost

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them £60, dealing with sludge would have cost them £130, and I think they would have required one man extra to look after the chemical works as compared with what they would require to look after the septic tank and contact bed. In 3½ years it would have cost Exeter £400 to deal with the 31,380 gallons of sewage. Now, assume—it is not a fact, but assume—that those beds are done for. Well, Exeter could afford to pay 10s. a cubic yard to renew them at the end of those years, and be £65 in pocket.

7722. What rate filtration per acre are you reckoning now?—I am reckoning what they are doing now that the 670 cubic yards are capable of dealing with 31,380 gallons daily.

7723. Have you reckoned out what it comes to per acre or per square yard?—I think they have a water capacity at Exeter of about 25 or 30, but I will work it out for you, sir.

7724. Supposing you put it in this way, would it be practicable, do you think, to deal with 5,000,000 gallons per acre?—I know nothing that would justify you in doing so on contact beds.

7725. You do not think even that quantity can be done?—I express no opinion as to what can be done; I know nothing that would justify it in practice. It may be so.

7726. You do not know of 500,000 gallons per acre being dealt with anywhere?—Not day by day. Let me guard myself. At Barking a portion of the sewage equal to one million gallons per acre is dealt with on their six foot bed, but I believe it to be true that when you come to deal with the whole of the flow, owing to the small quantity which comes in the night, and the big rush in the day, that you cannot get sewage through them at that rate.

7727. Can you suggest to us what rate is likely to be attained by contact beds?—Well, in practice, sir, what I do is to provide about 3 acres per million.

7728. Then the cost of renewing the material for 3 acres for 1,000,000 gallons would be roughly, if 4ft. 6in. depth, £6,000?—I have not checked that—it would be a very considerable sum of money.

7729. The whole question turns upon how often it would be necessary to do this?—That is so, sir.

7730. Have you formed any opinion yourself as to how often that would be likely to arise?—In the case of Exeter it has gone to 3½ years. I think I am standing on solid ground when I say it is good for 3½ years; how much longer I really cannot tell.

7731. Have you any idea where it is possible to deal with crude sewage on such filters at all?—Choking up would come on more rapidly.

7732. If they would require to be renewed every two years. Have you considered whether this cost of renewal would be quite an impracticable one?—Well, I would not like quite to go so far, but I should hesitate to put anything in that I thought was going to come to an end in two years.

7733. As to the cost of material to form filter beds, do you think that 6s. a cubic yard is a proper figure to take for any kind of material?—No, I think it will cost more as time goes on. I am burning some clay at the present time. The clay is on the ground; I am getting it put into the filters at 8s.

7734. Per cubic yard?—Yes, the contractor has a slight pull at that, but it is going to cost something about that.

7735. When people talk to you about clinker at 2s. 6d. per ton it is more necessary to consider what will be the cost per cubic yard than the cost per ton?—If anyone would make a permanent contract with me to supply all the clinker I want at 6s. per cubic yard I would settle with him at once; I think it is a very big difficulty finding all this quantity of stuff.

7736. I do not want to go except very lightly into the material to be used, but you think that 6s. per cubic yard as a basis of calculation is not in any way unreasonable?—I have not got any put in at less.

7737. In another part of your evidence where you were talking about land treatment you said that if an effluent from artificial filters is passed finally overland that you think it likely that a larger quantity than 30,000 gallons per acre could be dealt with provided it is not made to go through the land, but allowed to go along the surface?—Yes, I gave expression to that opinion.

7738. In flowing sewage along the surface will you explain what the method of procedure is, assuming the land is level. Do you mean that you flood the land?—No, I would let it run on, with a very slight gradient at the top, in as thin a film as possible, and let it flow continuously over it.

7739. And the land is not under-drained?—No.

7740. The sewage is not encouraged to pass through the land?—No.

7741. Some of it will pass through it?—Undoubtedly.

7742. A part of it will pass over it?—Will pass over it.

7743. What is the nature of the purification you get in that way?—It is only an expression of opinion. I do not know. What I want to guard myself against is that 30,000 gallons per acre represents the maximum that the best land will do.

7744. But you have experience of flowing sewage over a surface in that way?—Oh yes.

7745. And do you obtain much purification in that way?—Oh yes.

7746. Then what is the nature of the process?—I cannot tell you, I am an engineer.

7747. The sewage leaves behind it probably on the surface more suspended solids?—Yes, a few, a little—the same as ordinary irrigation.

7748. Obviously they must have been withdrawn if it does not?—Exactly the same as in all irrigation—whatever solids do not go through the land remain on the surface whether you put the water through the land or over.

7749. You find, in fact, there is a purification, but you have not investigated what the process is—whether it is a process of oxidation with or without a bacterial agency?—I know nothing about that.

7750. If a system of artificial filtration produced an effluent which had reached 80 per cent. of purification before it was put on the land you have not much fear that flowing it at, say, 20,000 gallons—or it is rather more—would bring about the remaining purification to bring it, say to 90, have you?—I should expect that, but if you asked me on what grounds I expected I would be in a difficulty, but I would expect it.

7751. I want to know what sort of results are obtained by flowing the sewage over the surface of the land in that way?—Take the Beddington Farm at Croydon. Very little of it under-drained, and it sends out very good effluent.

7752. And does the bulk of the effluent come out at the far end over the surface, or does it really come out underneath through drains or otherwise?—I cannot tell you the proportion, but there is a considerable bulk, the major portion, I should judge by the eye, does come over the surface.

7753. The flow at the far end over the surface seems to be nearly as large as the flow over the surface at the beginning?—I would not say nearly as large, but I should judge something between 50 per cent. and two-thirds—I should judge so.

7754. (*Professor Ramsay.*) Does it not make a nuisance?—No, Sir, there have been complaints at odd times of the Croydon farm, but substantially it is a well managed, successful farm.

7755. (*Colonel Harding.*) But where you have previously withdrawn almost the whole of the suspended solids from a sewage, do you not find the purification over artificial filters is more rapid and more certain than overland?—Oh, yes, I agree with you there that if you can give an artificial filter a definite quantity of work to do that it represents our best condition of dealing with sewage.

7756. You may deal with it really as an area of specially prepared land?—That is what I do regard it in my own mind.

7757. And artificial filters and land process are the same process over a larger area and smaller, that is your view?—I am taught it, and I believe it.

7758. You believe that view?—I cannot pin myself as to its truth except by my eye. I am an engineer.

7759. Returning to the important question we discussed some time since, you think that if a great manufacturing town can be induced in the first instance to deal with twice its normal flow, the first dilution being always a bad one that that ought to be expected as a first stage, but they ought to be told that later they will be expected to deal with at least two more dilutions?—Yes, at least two more.

Mr. Alderman H. F. HIBBERT, Chorley, Lancashire, called in; and Examined.

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7760. (*Chairman.*) You are, I think, Mr. Alderman Hibbert, of Chorley, Lancashire, a member of the Ribble Joint Committee and Chairman of the Chorley Sewage Works; County Councillor for the Borough of Chorley?—I am.

7761. Will you kindly give us an account of the Chorley sewage and sewage works, and of your own experience in sewage treatment?—The population of Chorley is 28,000, but only the sewage from 26,000 enters the Chorley Sewage Works, the remaining 2,000 being served by three small installations in low lying parts of the borough. The Liverpool Corporation, from whom Chorley obtains water, gives the daily supply as a little over 19 gallons per head of the population. The dry weather flow of sewage into the works is between 600,000 and 700,000 gallons per day. There is very little trade refuse in our sewage, which for all practical purposes may be called a domestic sewage. We have, however, to treat the effluent from three or four small breweries, one tannery, and the public abattoirs. All the storm, soil, and surface water enters the ordinary sewer. Our analyses have been made by Mr. W. Naylor, F.C.S. and A.M.I.C.E., Chief Inspector of the Ribble Watershed Committee, and Mr. Carter Bell, Analyst for the Borough of Salford, though we have had analyses from Dr. Bostock Hill and Dr. Thresh. We have used as precipitants ferrozone, ferral, and alumino ferric. The average proportion of chemicals per gallon used was last year 8·31 grains. The amount used, however, varies every day, according to the state of the sewage, the highest quantity used last year being 11·2 and the lowest 6·56. Our subsidence tanks have a capacity of 1,442,800 gallons. 526 tons of wet sludge, containing 90 per cent. of moisture, are produced each week. The sludge is removed every other filling of the tanks, otherwise it is more difficult to treat. The flow of sewage is intermittent. We have experimented with continuous flow but find it impossible to get perfect precipitation. Our filters are rectangular, containing about 1,400 superficial yards, with a depth of 3 feet 3 inches. The top layer of the filters is sand dredged from Fleetwood Harbour, the next 12 inches of polarite and sand mixed, and then graded down to small boulders of from 2 to 3 inches. Our rate of filtration is about 450 gallons per square yard per 24 hours. The filters are washed weekly. They filter more rapidly after being freshly washed, and slower, of course, towards the expiration of their time. The average quantity of sewage dealt with daily is about 700,000 gallons. The quantity is increased in time of storm, sometimes to the extent of twice or three times. In such a case we treat as much as we can over the precipitation tanks and filters, working continuous flow so long as the flow lasts. The remainder goes into the stream untreated. The precipitated effluent is distributed on the filters by means of syphons. The syphons unseal every 40 minutes, and cover the filters 3 inches deep with water. The capacity of the syphon chambers is 2,400 gallons. This quantity of water is therefore sent through the filters every 40 minutes. There is thus a layer of air between each filtration, or passage of the water through the filters, which undoubtedly purifies the interior strata. The effluent is examined at least monthly by the river authority; every day by us. The samples are examined as drawn, after shaking the bottle. An average analysis of the crude sewage would read as follows:—

Albuminoid Nitrogen	·66
Dissolved solids about	80·00
Suspended solids from	10·00 to 25·00
Chlorine - - -	9·00

The crude sewage is constantly varying owing to the rapid conversion which is being made from the pail to the water carriage system. This variation is caused by the emptying of the pails into the sewer. I have known the crude sewage to contain 5·0 per 100,000 albuminoid nitrogen. The works have been running since October, 1895, without any rest. We have not made any observations of the temperature. No nuisance has ever been caused by the treatment except when we went in for continuous flow as an experiment. We are still proceeding with the same treatment we have followed for the last four years. We should be glad to see the Royal Commission again, but they have already visited the works. I have experimented with continuous and quiescent flow in precipitation tanks, and have come to the conclusion that it is impossible with continuous flow to get as good results as from quiescent flow, either in quantity of water treated, or quality of the final effluent, if the said effluent has to be treated on a filter with a top strata of sand. I have also made exhaustive experiments on continuous and intermittent flow on filters composed of sand, polarite, gravel, the results of which prove that a water-logged filter will not produce satisfactory results, either in point of quantity or quality. I have also experimented on coke filters on the same lines, and with the same results. I have visited all the principal sewage works in Lancashire, and am conversant with the different methods there in operation, and as a result believ it is possible to treat sewage effectively by other systems than the one in operation at Chorley. I think, however, that none of them can produce an effluent as good as Chorley, in point of quantity and quality of gallons treated for the same expenditure, capital and current, in consequence of the greatly increased area of the filters. The system in operation at Chorley was started October, 1895. The works have cost 14s. 7d. per head of the population (26,000)—£19,000. The annual expenditure on current account is £1,373, or 1s. 0½d. per head, but including the payment of interest and sinking fund, the total charge per head is 1s. 9¾d. We commence the making of our own precipitant in a few weeks, when we hope to save at least 15s. per ton. We are at present lighting up a portion of our sewage works with gas made from our pressed sludge. This sludge is carbonised in exactly the same manner as coal, and gives off on an average 7,000 feet of 20 candle power gas per ton. We have also made sulphate of ammonia from the ammoniacal liquor, which is slightly better both in quantity and quality than the same bi-product from coal.

7762. (*Professor Ramsay.*) At Chorley the average daily flow is 600,000 or 700,000 gallons, is it not?—The dry weather flow is between 600,000 and 700,000 gallons per day.

7763. And the capacity of the tanks?—The capacity of the tanks is 1,120,000 gallons.

7764. That is to say, the tanks are about twice as large as the daily flow, roughly speaking?—Yes, they are twice as large as the dry weather flow.

7765. So that, supposing there is a dry weather flow, does any antiseptic action go on in the tanks?—None whatever.

7766. You do not allow it?—No.

7767. Do you clear the tanks periodically?—We clear the tanks every other filling, and would be very glad to clear them every filling if possible.

7768. Would it be possible to use such tanks as a septic tank?—Oh yes, as an open septic tank.

7769. But you purposely do not do so?—That is so.

7770. Then as regards the precipitants, you use ferrozone, ferral, and alumino-ferric?—We have used them all in turn.

7771. And have you any views as to which is preferable?—Personally, and my manager also, I prefer the ferral, which is made with sulphuric acid. In fact, we are just on the point of making our own precipitant. That is from economical reasons.

7772. Is there a patent?—No.

7773. You wash the filters?—We wash them every week.

7774. Can you tell us if the first effluents after washing are better or worse than the last effluents before washing?—I should be almost inclined to think that the effluents further away from the washing, that is when the filter wants washing, are better than the effluents from the newly-washed filter.

7775. Do you attribute that to bacterial action?—I cannot say, I do not know. Of course you lose a very large amount in capacity in order to get the better effluent, because the filters run very slowly when they have been working about seven days.

7776. Then you gain capacity by washing them?—Undoubtedly.

7777. How is the washing carried out?—The filters are worked in triplets. We have upward washing in each of the filters, and then we have a patent washing machine designed by myself, which rakes up the top four of five inches of sand, and mixes it with the water which has come through the filters. The sand settles

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first, and that which we take out in the form of mud lies on the top. This is then brushed off by means of very soft brushes, and gravitates to what we call our sand-wash water tank. After this it gravitates to a pulsometer, and is pumped back into the mixing channel for retreatment.

7778. The sand is pumped back?—No, the water. The sand is caught, the bulk of the sand remains, of course, on the filter bed itself, but any sand which escapes from the filter bed on its way to the sand wash water tank is caught by means of interceptors, and exposed to the action of the atmosphere and then used again. There is practically no loss of sand, I may say.

7779. The washing takes place practically on top of the filters?—Well, all the matter which has come in with the sewage from the precipitation tank is washed out. We find that it never penetrates more than four or five inches into the top layer of sand, which is some 8 inches deep. We simply get it out again.

7780. Unfortunately, I was not able to see the Chorley Sewage Scheme, so perhaps you will excuse this question: Do I understand it that you do not remove the sand from the top of the filters?—Oh, not at all; we have simply a revolving rake which stirs up violently the top four or five inches of sand, and mixes it with the water which has come up by means of the upward wash.

7781. You find a certain amount of nitrate, I think, in the effluent, do you not?—Yes.

7782. Which shows that bacterial action does go on?—So I am told. I should like to interpolate here that I am not a chemist, I am a commercial man.

7783. But your experience?—I am simply speaking from my own experience, and my analyses which I have to put before you are not my own but those of competent chemists.

7784. But the fact of nitrate occurring in the effluent would show that some organisms are present in your filters?—I am told by chemical men that bacterial action has taken place.

7785. You do not aerate your filters at all, do you?—Oh yes we do.

7786. Are they not worked continuously?—Oh no, I think the good results that we get in Chorley are almost solely owing to the intermittent treatment of the effluent from the precipitation tanks on the filters. They are worked by means of syphons, as I say in my evidence here. The syphon chamber holds 2,400 gallons of water. This 2,400 gallons of water is liberated by means of a syphon every 40 minutes. I ought to say it is liberated every 40 minutes when the filters are freshly washed. The filters get slower, which they do owing to their becoming much more dirty. Then it is customary with our people to stop the syphon, say, for an hour in order to allow the water in the syphon chamber—if you can follow me—not to overtake the water which is in the filter.

7787. But you allow the filters to rest after each drain?—No, they simply draw in the atmosphere with them, and then they are ready for a fresh discharge.

7788. How long does it take to draw in the atmosphere?—Well, we fill the filters by means of the syphon chambers every 40 minutes. We do that as a general rule.

7789. What part of the 40 minutes is consumed in running off the water?—We never let that completely run off. Our object is to run the water through the strata of polarite and sand, and as soon as the filter is partially emptied you fill it again?—We fill it again—yes.

7790. You use the expression, "quiescent flow," that does not imply continuous flow?—No.

7791. No special sample?—We fill our precipitation tanks with 140,000 gallons of water and sewage, and allow them to stand until we think the solid matter in the tanks has been precipitated. This is very carefully watched by the man in charge of the 8 precipitation tanks, and he never allows an effluent to go from the precipitation tanks on to the filters unless it is, in his judgment, in a satisfactory condition to go there. There is practically very little suspended matter in the effluent which is sent from the precipitation tank on to the filter.

7792. Can you hand in copies of analyses of sewage in Chorley?—Yes, there is one here by Dr. Thresh.

7793. (*Colonel Harding.*) Do you not have systematic analyses taken—regular analyses?—Oh yes, they are taken by the Watershed Committee.

7794. How often?—They are taken always once per month.

7795. Have you any average of those analyses per month over a long period?—Yes, I can give you that for the last three years, but that only gives the albuminoid ammonia in the filter effluent itself.

7796. What we all want is an average based on a large number of analyses?—Very well, the average for the year 1898 of the filter effluent from the Chorley precipitation works was ·094 per hundred thousand parts of albuminoid ammonia. The average for 1899, ·067.

7797. (*Professor Ramsay.*) The first figure was for 1898?—·094 for 1898; ·067 for 1899; and ·0775 for 1900. The average for the three years of all the samples taken by the River Watershed Committee at Chorley is ·076.

7798. Is that all your department?—Yes.

7799. They do not estimate the oxygen absorbed?—They do occasionally, but very, very rarely. They only take oxygen absorbed in my Watershed Committee where the sewage effluent itself is very foul, or very full of organic matter, and in that respect we differ of course from the Mersey and Irwell Watershed Committee.

7800. (*Colonel Harding.*) Have you any instances where the oxygen absorbed is given?—I have not; in fact I do not think it has ever been given for Chorley unless it has been given at my special request in order to compare it with some sample from the other Watershed Committee, and in that respect I feel bound to say this in the interests of those who are trying here to solve this very great difficulty, that I think it would be a very great deal better, at any rate, if the two Watershed Committees in Lancashire adopted as it were the same standard. You see in the Ribble Watershed Committee we pin our faith on albuminoid ammonia; in the Mersey and Irwell Watershed Committee they pin their faith on oxygen absorbed.

(*Mr. Killick.*) No, pin our faith on oxygen absorbed is rather a strong term.

(*Professor Ramsay.*) No, we do not do that, but it is a valuable point.

(*Mr. Killick.*) It is the note that is always taken, albuminoid ammonia is also always taken.

7801. (*Professor Ramsay.*) Always taken?—Yes, but it is not reported. As a matter of fact, I have here a list of the reports of the Mersey and Irwell.

7802. (*Mr. Killick.*) That is perfectly true. It is not reported?—Therefore anyone who wishes to compare what they are doing in their own particular works or my Watershed Committee are unable to compare it with what is being done in Mr. Killick's Watershed Committee. Here are two copies of the two last reports. One of them gives the oxygen absorbed four hours' test grains per gallon and nothing else; in the Ribble Watershed Committee we get parts per 100,000 albuminoid ammonia.

7803. I think the Ribble Watershed Committee is the only committee that use the albuminoid ammonia alone?—Of course I know nothing about that, but I have had a lot of conversations with the different chemists, both in your watershed and in my watershed, and I find a consensus of opinion in favour of the albuminoid ammonia. Of course, I do not attach any importance to that. What I mean to say is this, that it would be far better if the two committees took both the tests, and then we should be able to compare them if we gave oxygen absorbed and if the Mersey and Irwell gave albuminoid ammonia.

7804. I may point out to Mr. Hibbert that when an effluent is complained of the full analysis is sent to the offending authority?—I believe that is so, yes.

7805. So any authority in the Mersey and Irwell receiving a complaint is in possession of the information which we should like them to have?—The only thing I ask is the outside public, particularly the chairman of other works and watersheds should have the same opportunity.

7806. (*Professor Ramsay.*) Would it not be possible to let us have those analyses that you have had made in full?—I could get the Ribble Watershed Committee to send them to you if you mean the separate analyses upon which I based my average.

7807. I mean all the analyses you have made?—Oh, yes, you could have them with pleasure. This average has simply been got out by me for my own purposes,

for during the last three or four months I have been making a visit to all the principal sewage works in Lancashire to see what they are doing, because it is necessary now that the filter area in Chorley is going to be increased; I wanted to see if anyone was doing better in order that I might recommend my corporation to adopt other means of purification than those we had at Chorley.

7808. If you thought it desirable?—If we thought it desirable, yes.

7809. (*Major-General Carey.*) Is that owing to the increase of the sewage?—That is owing to the increase of the sewage and in relation to that I think I ought to make an explanation with regard to the flow of sewage at Chorley. I think I misunderstood the question to some extent, that is with regard to the dry weather flow of sewage into the works being between 600,000 and 700,000 gallons per day. Now, that is perfectly true, but the average amount of sewage which has gone through the Chorley works per day not of filtrate, but the average amount of sewage which has gone through Chorley works per day has been, in 1901, 1,274,477 gallons. Of course, a large amount of this, you see, is storm water, that is included.

7810. (*Colonel Harding.*) Has all that passed through the tank?—It has passed through the precipitation tank, but not all passed through the filters. In case of a storm where the flow approximates to three times the normal flow we are allowed to send it direct into the river without treatment.

7811. (*Sir Michael Foster.*) But after precipitation?—Well, without precipitation at all, but as matter of fact we do not do that. We send as much of this storm water (and it is principally storm water) as we possibly can through the precipitation tanks, and in that case, work continuous flow.

7812. (*Professor Ramsay.*) On to the filters?—No, it does not go on to the filters at all. There are eight precipitation tanks set on, four of them at the end have continuous flow in the treatment of this storm water, the remaining tanks will be used for the purpose of serving the filters.

7813. Do you draw any distinction between the first flow of the storm water of the subsequent flow?—Yes, we always impound the first flow of storm water because it seems to—I was going to say scrape out the sewers. At any rate there is an enormous amount of growth on the sides of the sewer which is liberated by the first rush of the storm water, and we always take care to impound that; in fact, it will come down as black as ink for a few minutes, probably 20 minutes, until the sewers have been thoroughly cleaned out by this rush of storm water.

7814. (*Major-General Carey.*) How do you separate the water which is going on to the filters from the water which is going on straight away to the tanks?—We have an arrangement by which we can deal with water in that way. We have separate channels. We have overflows attached to our two-end precipitation tanks so that we can deal with continuous flow either through the whole series of eight tanks or through the two end ones, or connecting with them any number of the tanks, so that we can work at the same time continuous flow of sewage which has been treated with the precipitant and quiescent flow of sewage, that is allowing for precipitation over our filters at one and the same time.

7815. A proportion of the total volume goes to the filters?—Exactly; our filters absorb as much of this water as they can possibly do, so they are never stopped.

7816. How do you separate the water that is going straight to the stream from the sewage which is going to the filters?—Well, we have two different channels.

7817. (*Professor Ramsay.*) But you do not separate the different amounts. You merely treat some of it and let the rest overflow?—We treat a portion of it as much as we can over the filters, the remainder we will send through four precipitation tanks, and send it direct into the stream after precipitation, only it is not quiescent precipitation; if you understand what I mean, it is continuous flow.

7818. (*Mr. Killick.*) You say you are allowed to send it into the stream at three times?—That is so.

7819. By whom, by the Watershed Committee?—The Watershed Committee.

7820. And the Watershed Committee require you to treat?—I ought to say by the inspector

7821. You are a member of the Watershed Committee?—I am.

7822. Is there any resolution of the Watershed Committee?—I think not.

7823. (*Major-General Carey.*) What chemicals are you using now?—We are using at the present moment alumino ferric.

7824. Have you given up ferrozone?—We have given up ferrozone, because it went worse; it was not as good in quality as it originally had been. Then ferral came on the market, and we used it for a considerable time, then we found we could make the precipitant ourselves considerably under the price we were giving for ferral, and we thought as commercial men we were justified in doing that. When the manufacturers of ferral were told that we were going to discontinue the use of it, seeing we were the largest customers they discontinued making it. We were thrown on our beam ends unless we used another precipitant. We then got alumino ferric. We got very good results from alumino ferric.

7825. In what proportions?—The average for the whole of last year grains per gallon 8·31.

7826. Per gallon?—Per gallon a year before that a little less, 7·37.

7827. When you were using ferrozone you were using from 20 to 30 grains per gallon, I think?—That is so, yes; but I think I ought to say in defence of ferrozone that we did not mix our precipitant with sewage as well as we mix it now. We happen to have a very good man as manager of our works, a very ingenious man, and we allow the sewage to rush through the holes in the sides of our mixer instead of falling on to the top of the precipitant. A great mistake in my opinion in using alumino ferric in all the different works is that it is placed in iron cages in the bed of the stream. Now, certain portions of the alumino ferric are softer than others, the consequence is that the action of the sewage honeycombs the precipitant, and then ultimately breaks it off. We were doing the same thing both with ferrozone and ferral, and one day my attention was called to the fact by my manager that the bottom of one of our precipitation tanks was covered with small particles of precipitant, varying in size from the head of a pin to probably as large as a pin. We got this up, and we found it was the precipitant which had actually been broken off. This was the time when we were using from 20 to 30 grains, when we introduced the new machine, and the new precipitant we found that it all went in solution. We had none on the bottom of our tanks, and our grains per gallon dropped to the figures I have given you.

7828. But what is the object of drying it. As far as I understood you take the deposit and grind it?—Well, we have not started yet.

7829. My question refers to what you were going to do; are you going to use dry precipitant or in solution?—Dry precipitant.

7830. Why dry?—As a matter of fact we want to use it the same as the other precipitants. They have been used in a dry condition.

7831. If I do not misunderstand you you treat the deposit with sulphuric acid and water, and heat it?—No, it boils itself. The action of the sulphuric acid is sufficient.

7832. Is it filtered or allowed to settle?—No, it gravitates into wells prepared to receive it; it is allowed there to cool; when it is cool the process is ended, and we rigged up an arrangement by means of which we could undoubtedly have saved considerable ferrozone itself, but still it was much softer; it was much more soluble in water, and we got through an abnormal quantity of it; we got through from 20 to 30 grains per gallon, and we thought that it was costing us so much money that in the interests of the ratepayer we should try to do better. We adopted ferral, and we got quite as good results, if not better results, and we use, I should think, half the amount of precipitant. I take it that both ferral and ferrozone are practically the same thing, probably cooked a little bit differently.

7833. Is there much difference in the cost?—Well, alumino ferric is dearer than either of them. We paid about 40s. a ton as far as I can remember for both ferrozone and ferral, and for alumino ferric we pay 47s. 6d., and we do not get any better results; we get quite as good, but we do not get any better. The pre-

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cipitant we are going to make ourselves is practically going to be made like the ferral was made. We get bauxite, and we put a disintegrator down, and we grind it. Then we treat it with sulphuric acid and water in certain proportions, in a large mixer we have built, and then it gravitates into two wells underneath the mixer, and cools, and is then dug out.

7834. Is your effluent always kept up to the same standard?—Well, the Ribble Watershed Committee consider that ·1 per 100,000 parts is good; our average, as I have already pointed out, has been considerably under that.

7835. (*Professor Ramsay.*) Then you do not dry your precipitant at all; you use it as a solution, I daresay?—No, we do not use it as a solution at all; we use it as a dry precipitant, but we put it in two rotary screens that we originally got on the works to wash our sand. These screens move in an opposite direction; they are perforated with small holes. Our precipitant is a solid mass; it is cut out.

7836. Then I want to ask Mr. Hibbert about the utilisation of the sludge. You are at present lighting up a portion of your sewage works with gas made from the sludge?—Yes, we are lighting up the offices, and we are lighting up the building we put up for the purpose of making the precipitant. As a matter of fact, the joiners working in this place have worked two hours every morning and two hours every evening by the light of the gas made from our sludge during the whole of this winter.

7837. How is that sludge dried, is it pressed?—It is pressed of course in the first instance, then we have taken the cakes out bodily, and placed them on the top of the boiler, where we generate steam, and we have reduced the percentage of water, which in the beginning would be probably about 50, down to 2½, or considerably less than the amount of moisture in coal. This we have carbonised this dried sludge in exactly the same manner that we should carbonise coal.

7838. Have you a gasometer to store the gas as usual?—Oh, yes, we borrowed from the gas works a small gas-making plant, which they used for testing coal, and we put it up in the sewage works, and made a series of tests. I can give you the tests if you wish to have them.

7839. It would be very interesting to have them?—Roundly we made 34 tests of 2lbs. each; of course the retort we had to use was a very small one. We made 34 tests of dry sludge, and the average was 7929 feet per ton. The illuminating power was tested at the gas works, and the gas manager reported that it was 20 candle power. The tar and ammoniacal liquor combined were 560lbs. of liquor to the ton. We have also tested the liquor, and we have made sulphate of ammonia out of it.

7840. You do not know the limit of sulphate of ammonia yet I suppose?—I cannot tell you, but the chemist who examined the sample for me told me that the quantity of ammoniacal water from this sludge was slightly better than that from coal.

7841. And in this installation, do you do anything with the residue?—No, we have experimented in many directions with regard to the ash or coke. We have tried to make cement of it, we have tried to use it for manure, we have tried to use it for mortar, but, although we find there is about 2½ per cent. alumina in it, we have not found out any useful purpose to which it can be put. At the present moment we throw this coke or ash on the bauxite on the store of bauxite, and grind it up with the bauxite.

7842. Does it burn?—No.

7843. The residue in the retort would not burn?—I do not think so.

7844. It does not contain coke?—I do not think so.

7845. (*Sir Michael Foster.*) What is the composition of it?—You say there is a small quantity of alumina, what is the rest?—I could not tell you, sir; though I could get the information for you easily. I mean to say, I cannot remember it.

7846. (*Professor Ramsay.*) Is it your opinion that it would compete with gas made from coals? Of course the material costs nothing, but is there any objection to using it in that way? Does the drying it, and handling it involve great expense, and buying coal?—I think with coal at the present price—15s. 6d. per ton for carbonising purposes, we could, undoubtedly, use all the sludge made at the sewage works with very great advantage to the ratepayers; whether that would be the case when coal got down to 7s. 6d. per ton, I should not like to say.

7847. (*Colonel Harding.*) Have you made an estimate of the cost of the gas that you produce?—We have not. Our Corporation are buying a new experimental plant for testing deliveries of coal. We shall be able then to store 10,000 or 20,000 feet. When we can do that, we shall go into the estimates, but we find this, that owing to its possessing less moisture than coal—this is the dry sludge, and it has cost us nothing to dry—it has cost us less for carbonising.

7848. (*Professor Ramsay.*) I suppose it is quite valueless as manure?—No, it is not. At this present moment, although we are making over 7 tons 10 cwt. per day of dry sludge, that is sludge out of which the 90 per cent. of water has been extracted; although we are making that I do not suppose there is a ton of sludge on the Chorley works at the present moment. The farmers take it away. They pay us 9d. for a one-horse load, and 1s. for a two-horse load. For two years after the works were started, that is up to October, 1897, we gave this sludge to the farmers; we only decided to charge for it when we found it possible to pick out the fields that had been manured with it. There was no boycott as in the Burnley district; they immediately came for it, and they paid for it, and we have not a ton on the place, as I have said.

7849. Then what is the position of the sludge that is used for manure and the sludge which is used for gas making?—We use such homœopathic quantities for gas making that it does not count.

7850. But, supposing it were suggested that this substance might be used instead of coal for making gas?—We should undoubtedly use it for gas making.

7851. As being more profitable?—Undoubtedly, I think we could try it at a very small expense; in fact, taking the cakes out of the sludge presses and simply standing them on end in the sludge press house in a week takes 20 per cent. of moisture out of them without any attempt to dry it, and I think it would be quite possible to utilise the heat from the chimney flue to effect the evaporation of the water at no expense at all except the handling of it. In fact, we have just got a new gas manager, and he looks with very great favour upon the utilisation of sludge for gas making purposes, and is going to conduct a series of experiments himself.

7852. If you can get 20-candle gas out of it, it is a great improvement on ordinary coal, which only gives 14 per cent.?—Well, up to quite recently, our gas manager was tied to make 21-candle gas.

7853. He could not get it from ordinary coal?—No, he had to make it from Cannel coal; but the gas we are making at the Chorley Sewage Works is better than at the gasworks, which has dropped its standard now to about 18 or 19.

7854. (*Chairman.*) When you say the farmers take it, that is the moist sludge without your drying it at all?—I think the moist sludge would contain about 50 per cent. of moisture. The farmers take it that way.

7855. Take it in its moist condition?—Yes.

7856. (*Colonel Harding.*) As sludge, or as cake?—As cake, yes.

7857. You do not use the sludge with the 90 per cent. in it; you use the pressed cake?—The pressed cake, which we dry.

7858. (*Chairman.*) Do you consider the precipitant that you use improves the quality of your sludge; that it makes it more suitable for making gas at Chorley?—I am not a chemist, but I should not think so.

7859. You should not?—No, I should not. I think if you could get sludge without using precipitant at all that that sludge would be worth infinitely more for gas making. In like manner, if you could press sludge without using lime it would be worth infinitely more for manure.

7860. (*Professor Ramsay.*) Does the compressed sludge ever putrefy and go bad? Does it make a nuisance?—No, not at all. As a matter of fact, we have little opportunity for determining that, because it is taken away every day; but we do store some 200 tons of this sludge for our own Corporation farm. Our own farmer uses it, and uses it to very great advantage, and he prefers to have it a year old. It then falls, and it is very much in the nature of loam. Well, when you dig into it, it is very warm, and it does give off smell undoubtedly; but when the sludge is standing it is un-

doubtedly sealed; the outer covering of the sludge seems to keep in all the ammonia which otherwise would escape and cause a nuisance.

7861. (*Sir Michael Foster.*) I gather that you wash your filters really because they get choked?—That is so.

7862. Do I understand that the filtrate improves right up to the time that you clean?—That is so.

7863. So that if you did not clean you would probably get a still better effluent if you were not obliged to clean?—You would get none at all.

7864. If you were not obliged to clean you would probably get a better effluent?—Undoubtedly the last drop that you get would be the best effluent, but it would be drops. We are obliged to clean the filters, otherwise they choke.

7865. I forget whether you have made observations with anything besides the polarite or without the polarite, I mean?—Yes, I have experimented with coke breeze, with coke, and with gravel, at any rate for months at a time.

7866. And you have come to the conclusion that the polarite is much preferable?—Well, I have come to the conclusion that no works in Lancashire, and I only speak for Lancashire, are getting the same results that we are getting. If they were, we should copy them and alter our own system.

7867. Yes; but that is your system as a whole?—Our system as a whole.

7868. (*Professor Ramsay.*) Is it not specially dependent on good management; have you not been more than usually fortunate in having competent managers?—We have only had one manager, undoubtedly a very clever man. He started in Burmah, and has had a most varied career, but he is undoubtedly the best manager I have ever come across. There is not one single piece of machinery on our works which that man cannot take to pieces and repair, too.

7869. (*Colonel Harding.*) How far are the results you have obtained due to the use of polarite in your filters?—Well, that is hardly a question I can answer. I started by telling you that I was not a chemist, but I was simply a commercial man. I have made a very great study of this question for the last ten years; I have made a great hobby of it.

7870. Have you tried your filters with and without polarite?—We have not tried existing filters with and without polarite, because they were laid down five years ago, and they have been more satisfactory than any filters I know. I have experimented myself with coke for the last few months because it was becoming necessary that we should duplicate our filters, owing to the increase in our flow, which five years ago was only 750,000 gallons, including storm water.

7871. Is your present impression that polarite is distinctly useful; but would not other filtering material of the same size?—My impression is this, that taking into consideration the cost of making a filter and the quantity of water it will turn out of a satisfactory character that no filter in existence, or no filter, so far as I have seen, can compete with the polarite filter. Speaking of other filters, take, for instance, the first and second contact beds at Burnley. The Burnley people are doing undoubtedly a very good work. I find that their average analyses for last year is only a little under that of Chorley. It is ·0844 against Chorley, ·0775, whilst the standard of purity called good by my watershed committee is ·1, so that here you have a system working on distinctly different lines to Chorley, and yet producing, comparatively speaking, quite as good a result. Well, that makes it difficult to answer the question you have asked me, and I can only add to what I have already said this, that the cost of making the Burnley first and second contact beds, without any regard to the fact that they will probably have to be renewed, for they are filling up, would be greater for filling with a specified quantity of gallons than the cost of making a Chorley filter to deal with the same amount.

7872. (*Sir Michael Foster.*) You said you have made experiments with coke?—Yes.

7873. But does that mean that you have constructed filters like your filters at Chorley, putting coke where you have put polarite?—No; I have not done that.

7874. You have not done that?—I have made filters consisting or composed of 3 feet of coke like the Burnley coke, only that the Burnley coke are made of engine ashes and the Chorley experimental filter was made of coke.

7875. But you have constructed no filters in which you have substituted for polarite some other material?—Yes, we have; we have constructed three filters in which we substituted magnetite instead of polarite. We did not get as good results because I did not consider the magnetite was well graded, but the result was well within the standard required by our Watershed Committee from the magnetite filters.

7876. (*Chairman.*) Do you know the proportions of the polarite and the sand? I see you say "the next 12 inches are polarite and sand mixed"?—Our top layer of our filters is 8 inches of sand, and beneath that we have, so far as I can remember, about 12 inches of polarite and sand mixed together.

7877. And do you know of that polarite and sand mixed together about how much is polarite and how much is sand?—About thre parts of polarite to two of sand.

7878. (*Dr. Russell.*) I noticed you said magnetite was not well graded, was that with reference to the size of the particles?—That is so. That is my own impression and that of my manager was this that if the magnetite had been supplied, screened as well, and of similarly sized particles to that of polarite we ought to have got as good a result.

7879. Probably; I did not see a sample of polarite, or if I did at Chorley I do not remember its physical appearance. What sized particles would they be; they would be larger than sand of course?—Oh, yes; I should think on an average about a quarter of an inch cube, an irregularly shaped figure, of course, but it approximates as closely as I can think of anything to a quarter-inch cube.

7880. So that the mixture of the sand and polarite forms a stage in an increasing grade from sand at the top to small boulders of from two to three inches at the bottom?—That is so; it undoubtedly acts as a mechanical filter. I do not know what other effect it may have. Of course, the polarite people told us that it contained an abnormal quantity of oxygen, and as we were then working under continuous flow, our results were getting worse every day. I said to my vice-chairman that it must contain an enormous quantity of oxygen if it will continue giving it off hour after hour without being exhausted, and we came to the conclusion that was not the case, and that is the reason we adopted intermittent flow, of which we had never heard until that moment.

7881. And you came evidently to the practical opinion that the mechanical condition of the filter dependent upon the size of the particles of this magnetite or polarite or whatever else you use is the important element?—Undoubtedly.

7882. (*Mr. Killick.*) You are a member of the Ribble Joint Committee?—Yes.

7883. Would you mind answering one or two questions with regard to the committee?—If I can, with pleasure.

7884. Have you been a member from the beginning?—No; I think I have been a member six years.

7885. Have you reason to believe that the work of the purification of the Ribble has been improved by the action of the committee?—Well, I should think it must have been improved. It is very singular you should ask me that question because only yesterday I was talking to a friend, and he said, "Well, we are spending an enormous amount of money in our Corporations on works in improving the rivers (confining myself to Lancashire), yet the flow of the Ribble does not seem to be in very much better condition." I answered him, as I answer you now, that an enormous amount of purification must have been effected. Of course, I might go further, and say this that there are very few works in Lancashire which are dealing with half their flow.

7886. There are more purification works on the river now than there were before the formation of that committee?—Undoubtedly.

7887. Then you think the formation of that committee has been a good thing—I do; I think it has been a very wise step.

7888. And have you ever thought of the question as to whether the formation of the watershed or Rivers Committees should be made compulsory instead of optional as at present?—I think it ought to be made compulsory.

7889. On the question of standards do you think it

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is advisable to begin the work of purification on the watersheds with a standard?—I think it would be wise to give a standard in Lancashire, I speak for Lancashire only; I think it would be wise to fix a standard in Lancashire, I think it would be equally wise for both watershed committees to work to the same standard.

7890. What do you think that standard should be?—I should be quite willing to adopt the present standard.

7891. And you would make that apply to all works wherever situated on the river?—I should make it apply to all municipalities.

7892. All municipalities?—Of course, you get into very much broader questions when you get to dealing with the works.

7893. I mean sewage works. I do not mean manufacturers' works. You would take the same standard for all?—I should; I should take the same standard undoubtedly to start with. It might be necessary afterwards, say in cases like Rochdale, where they have to deal with an enormous quantity of wool scourings, to slightly enlarge the standard, because their difficulties are undoubtedly greater than they are at a place like Chorley, where we only deal with domestic sewage.

7894. But an exception of that kind might be left safely to a committee which represented the Rivers Board?—Undoubtedly.

7895. (*Colonel Harding.*) First, a question on the points raised by Mr. Killick. You expressed, I think, a bitter disappointment, or at least surprise, that although something was being done in Lancashire in the way of sewage treatment, there was no very evident improvement in the condition of the rivers, did you not?—Oh, no; I did not say that. I said a friend of mine had told me that he did not think there was much improvement. I said there must be improvement according to my own observations.

7896. You assume that there must necessarily be improvement, more things being done?—Oh, there is bound to be.

7897. I wish to remind you that the population of Lancashire is being largely developed, is it not?—Yes.

7898. And the industries of Lancashire also?—Yes.

7899. And probably if it had not been what has been done by your board in compelling some purification the condition of things would have been not the same, but infinitely worse; and therefore if it is not worse, the fact that it is not worse, notwithstanding the increase of population and industry, may be considered to be due to the efforts of your board. I want to press that?—I think it is impossible to conceive what would have been the condition of the rivers in Lancashire if it had not been for the action of the two Rivers Boards, which have worked all along not to harry manufacturers into doing this but to try and persuade them.

7900. But what is being done is nothing to what must necessarily be done; ultimately a further improvement must necessarily follow?—Further improvement will undoubtedly take place, because a great many of the governing authorities in Lancashire are waiting for the decision of this Court, and I think very naturally so, too.

7901. You suggest to us, I suppose, that the interest of your installation at Chorley lies in this, that it may be looked upon as a model instance of chemical treatment of sewage, followed by filtration?—Of course it is my own works, and I hardly like to put it so strongly as that. I can only say this, that on the average of the last three years the Chorley sewage works are at the top of the districts in my own watershed, purifying their sewage, and that fact, of course, speaks for itself.

7902. But you do not know of a better example of chemical treatment than yours at Chorley?—I do not know it.

7903. You do suggest to us that we may look upon it as a sort of model instance of chemical treatment?—Well, I think you perhaps might.

7904. I do not in the least suggest it is not so. I merely make that point in passing. Well, now you are aiming there, in the first instance, at the most complete and thorough settlement of the suspended solids?—Yes. Well, we will take the 1·8 and leave the ·89 out.

7905. 1·8 is very considerably in excess of the statement you have given us. You have given us here ·8 the sewage?—That is albuminoid nitrogen, not albuminoid ammonia. I reduce my albuminoid ammonia to terms of albuminoid nitrogen.

7906. (*Professor Ramsay.*) There is not very much difference; it is only the proportion of 14 to 17?—14-17ths, so that you have taken as 14-17ths of our albuminoid ammonia, which will bring it to ·9, a little over perhaps.

7907. (*Colonel Harding.*) That is materially different from 1·8?—Yes, the organic ammonia in this sample was 1·8 in te raw sewage, the tank effluent from the same was ·22, so that 1·8 was reduced to ·22.

7907*. By the settlement of suspended solids?—That is so, yes.

7908. (*Professor Ramsay.*) After treatment with alumino ferric?—That precipitant, yes.

7909. (*Colonel Harding.*) By chemical settlement?—Yes, and the same going through the filters was ·072 parts per 100,000.

7910. Then have you any data as to the suspended solids in the effluent?—In the final effluent?

7911. No; the effluent before it goes on to your filter?—No, there are very few.

7912. It would be practically clear?—Practically milky.

7913. So that by quiescent settlement you suggest to us that sewage may be with suitable precipitants absolutely settled?—That is so.

7914. And, therefore, the subsequent filtration would be immensely assisted?—Undoubtedly.

7915. And the danger of choking filters very greatly reduced?—That is so.

7916. And with an effluent almost completely free from suspended solids you are able to filter through a fine material like sand?—Yes.

7917. And you have moved from continuous to quiescent settlement for the purpose of accomplishing that?—Well, we have always had quiescent settlement.

7918. I believe you told us that you had experimented with continuous settlement?—I did.

7919. And because you did not get such good results, I suppose more suspended solids came out, you returned to quiescent settlement?—As a matter of fact, our filter was choked. I do not say for one moment that continuous flow will not do for a bacteriological filter where the sludge is allowed to walk over.

7920. What I want to obtain is, where a settlement of suspended solids is possible your experience goes to show that quiescent settlement is superior to continuous flow?—I am absolutely certain.

7921. Can you tell us any results, for instance, of the amount of suspended solids coming out in your effluents from the quiescent settlement?—I should like to give you Dr. Thresh's analyses; that will answer the question. In one analysis, and I may say also that these samples were very thoroughly taken; that is, the same sewage appears through all, in other words, a tank was filled, the same tank was allowed to precipitate and the same tank was filtered.

7922. Well, can you give us the figures?—The organic ammonia in two samples, one taken at 1 p.m. and the other at 2.

7923. Crude sewage?—Crude sewage was in one case 1·8 albuminoid ammonia and in the second one 8·96. Now this was occasioned, of course, by the emptying of the pails. We are now changing from the pail to the water-carriage system, it was occasioned by the emptying of the pails into the sewage.

7924. But that is a very exceptional condition, is it not?—Well, of course, this occurs every day, but only for a limited period.

7925. Cannot you give us something which will be more typical of general conditions?—With continuous flow it would be impossible to use the sand filter, absolutely impossible.

7926. And I think you have recognised that that impossibility is due to the necessity for aeration?—Undoubtedly.

7927. Which you obtain by intermittent flow?—Without aeration it would be impossible to get our sample.

7928. And I think you have expressed in answer to a question by Professor Ramsay that that was probably a bacterial result?—Very likely.

7929. Then the point comes, which is that by thorough precipitation by quiescent settlement and by suitable precipitants you are able to use a fine filter?—Yes.

7930. And you are enabled to tell us how far polarite as such has any value; you have not as yet tested a layer of material similar in grain to the polarite you use so as to be able to tell whether polarite as such has any value over, say, clinker under precisely the same circumstances?—Well, we have had coke and magnetite; I think I answered the question only magnetite.

7931. But in regard to magnetite you believe magnetite would have given the same results if the same sized material had been used?—Yes.

7932. Do you think with clinker again in the same way you would get the same results?—No, we tried it; we cannot get the same results.

7933. The same result cannot be obtained?—I do not think there is the same purification through clinker or coke as through polarite; I do not think the particles are fine enough. It is undoubtedly mechanical filtration.

7934. If clinker was of the same size as the polarite that you use do you expect that you would get different results than from polarite?—Yes. I do not think I would get so good; it is more porous.

7935. Do you attribute that to the porosity of polarite?—Yes.

7936. You suggest that the action is due to the porosity of the polarite, and that the liquor passes through the body of each particular piece?—No, I do not.

7937. If not, what is the use of its porosity?—I know, as a matter of fact, that polarite will filter water; I have tried it. I have taken large pieces of polarite and cut into them, and put water into them, and filtered water through them. It will do that, but I certainly should not contend that any but a very small quantity of the water does pass through the polarite.

7938. Then you say that porosity of the polarite effects its utility as a filter as compared with clinker of the same size?—Well, you see a polarite filter is made up of sand and polarite.

7939. Assume that where you have polarite you put clinker of the same size as polarite and keep the sand exactly the same?—Of course, I cannot express any chemical opinion on the matter, but in all the experiments that I have conducted with cinder or with clinker or engine ash I have never been able to get the same results.

7940. But you have not tried them with the same conditions?—We certainly have not tried clinker or cinders with sand, but we have tried them in other forms. I will put it in another way. I think you will get a more rapid filtration through sand and clinker than you would through sand and polarite.

7941. Of the same size?—Yes, undoubtedly.

7942. Why?—Because only a very small percentage of the effluent went through the polarite, it would undoubtedly go through the sand; but if you had clinker or cinders in place of the polarite you would have more of the effluent going through the cinder than you would through the sand. It would filter more rapidly than through the sand; therefore, your filter would become infinitely quicker.

7943. We are speaking now of clinker versus polarite. I am assuming that you use the sand in exactly the same way with clinker of the same size as the polarite. Would you not then get the same results?—No, for the reason I have just explained, that the filter would work too rapidly.

7944. Why too rapidly; size of the clinker the same size as the polarite, the same sand above it?—Because the clinker would filter quicker than the polarite. If you had two separate tanks, and filled one with polarite and the other with clinker exactly the same size, this would be emptied in one tenth of the time that would.

7945. Can you suggest to us why?—I cannot, I would leave that to scientists to determine. Undoubtedly there is something in the action of polarite on the sewage; what it is I do not know. I do not believe it arises from an abnormal quantity of oxygen, but it arises from something.

7946. Anyway you cannot explain it?—I cannot explain it.

7946*. (*Sir Michael Foster.*) Does any change take place in the polarite after it has been at work for a long time?—When we had worked our filters five years last October we had occasion to take up one of our filters in order to lead the supply from our sand wash water tank to a well in order that it might be pumped back for retreatment. We took out each strata, we found the polarite as sweet as the day it was put in, and we found that there was no disintegration.

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7947. (*Colonel Harding.*) It cannot have given up oxygen to any important extent?—I do not suggest that at all, I only tell you what the patentee said about it; but whether it contained oxygen or not my experience of polarite ranging from six years is that we get a better effluent from polarite than any other body in Lancashire can get through cinders.

7948. (*Sir Michael Foster.*) But you think it is chiefly because the polarite makes the material go through sand? I think, to a very great extent, it is because it is a mechanical filter. At the same time, some chemical action takes place; what the action is I cannot determine, because I am not a chemist.

7949. (*Colonel Harding.*) Are you proposing to make experiments on various materials before you extend your filters?—We are proposing to extend our filters with polarite, and the only difference I am going to make is this, that instead of the filters containing 100 square yards superficial they shall contain 200. This will extend them lengthwise.

7950. Are we to understand that you are going to double the area of the filters?—Yes.

7951. For a given volume of sewage?—In this way, that is the present filter, here is the distributing channel, and here is the syphon chamber, with a syphon in it. At the present moment this distributing channel passes 2,400 gallons of water in here. That flows into there every 40 minutes. I propose now that this filter should be lengthened to double the length, instead of sending 2,400 gallons over here in 40 minutes it shall send 2,400 gallons over the entire double length in 20 minutes. Instead then of getting aeration once in 40 minutes from this filter I get it one in 20 minutes.

7952. The area relatively to volume would remain the same?—Yes, instead of having four inches deep of water at the top of the 100 yards filter, I shall get two inches; I shall get an extra layer of air to purify my filters every 20 minutes. It is simply so many more fillings every day?—Yes.

7953. (*Major-General Carey.*) What is the thickness of the polarite?—About one foot, and the sand eight inches.

7954. (*Professor Ramsay.*) Do you take any trouble about your fillings?—There is a patent apparatus, really a trough, with pores, perforations, much in the shape of this, having a kind of splash-board on the bottom to prevent the water splashing on the filter itself. By means of this I can flood the surface of practically 100 square yards with the effluent from the syphon chamber in one minute, so that in one minute I get the whole of the filter working. Before that it was simply distributing at the mouth here by means of a trough, like everywhere else, it ploughed up the sand at the entrance of the filter, mixed the clean with the dirty sand, and took three minutes to fill the filter. We lost two minutes, and now we economise to the full the area of our filters.

7955. Do you require to clean the distributor at all?—No.

7956. The material that goes on is so clean that there is no necessity?—Quite.

7957. (*Dr. Russell.*) Have you any idea what this polarite really is?—Well, I do not know. I think I wrote it down somewhere; I could not remember; it was a highly ——

7958. That is what it is described to be?—I will give it up.

7959. (*Colonel Harding.*) The results that you gave us in regard to albuminoid ammonia are, I take it, very satisfactory to your Board?—Yes.

7960. I notice that at Manchester the oxygen absorbed is relatively higher than their albuminoid ammonia, and I should have been interested to know if you could give us any result, even a single result, in regard to oxygen absorbed?—I can give you the oxygen absorbed on the same sample of Dr. Thresh's report.

7961. Well, what is the oxygen absorbed in the final

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filtrate?—Oxygen absorbed in four hours in the final filtrate ·36 one sample, and ·17 the other.

7962. That would be in harmony with the good results of albuminoid ammonia?—I think your standard is about one grain.

7963. (*Mr. Killick.*) In the ordinary way, the two tests run together very closely?—You see, with regard to Manchester, you must take this into consideration, it is a very weak sewage.

7964. (*Colonel Harding.*) In Manchester?—It looks a dirty sewage; but, as a matter of fact, in organic impurities, it is very weak. I should not think that the organic impurities in the Manchester sewage, from what I have heard, will be much above ·4.

7965. Well, we will deal with Manchester sewage when their time comes. Now, good results, in the opinion of your Board, having been obtained by this system, it is interesting to us to know at what cost it is attained, and whether the means you are using are permanent. I understand it has been at work four years?—Five and a half.

7966. And you can work for a considerable period without renewing the material, and so on?—Yes.

7967. And the cost you tell us is 1s. 9½d. per head including interest on original outlay?—The total cost per head of the population is 1s. 8½d.

7968. 1s. 9⅜d. you state here, on page 5 of your memorandum?—Oh, yes; the annual expenditure on current account is £1,373, or 1s. 0½d. per head; but, including the payment of interest and sinking fund, the total charge per head is 1s. 9⅜d. Yes.

7969. That is the maintenance charge is 1s. per head?—Yes.

7970. So that for a population like that of Manchester, if you take it at 500,000, that would be £225,000 a year for maintenance?—Yes.

7971. And, notwithstanding, you think that is the most economical way of dealing with sewage?—I do.

7972. Then that includes, 1s. per head, the whole cost of treating the sludge?—Yes.

7973. But you are very favourably placed, are you not, for the disposal of sludge; that is, you are a small community in the midst of a large agricultural area, and you have relatively a large number of farmers who can use it?—That is the condition of nearly all the Lancashire and Cheshire towns. As a matter of fact, we have more agricultural land in Lancashire than they have in Cheshire, although Cheshire is an agricultural county.

7974. Would that apply to Manchester?—Probably not to Manchester, which is a very large city.

7975. I am wanting to know whether the system you are successfully working there is applicable to large communities. You tell us that you produce 526 tons of wet sludge containing 90 per cent. moisture a week?—Yes.

7976. And you do so with a normal flow of 700,000 gallons?—Yes; I have explained that that is the dry weather flow.

7977. The dry weather flow is 700,000 gallons?—Yes, but the average flow for last year, as you pointed out on going through the works, was 1¼ millions; the sludge comes from the 1¼ millions.

7978. That is the total flow?—That is the total flow, but that goes through the works, and from that flow the sludge proceeds.

7979. With a normal flow of 700,000 gallons you produce 526 tons of sludge a week?—Oh, no, we do not; from the 1¼ millions we produce that.

7980. With a normal flow of 700,000 gallons, which occasionally is increased, you produce 526 tons of sludge?—No, we do not; that is not our normal flow.

7981. Will you state it?—I have already stated that our dry weather flow——

7982. The average sewage dealt with daily is 700,000 gallons?—Exactly. As I explained at the beginning, I dealt with the amount of water which practically went over our filters or went through a quiescent precipitation tank, that in addition to that there was a large amount of water making the difference between that and the 1¼ million gallons, which went through the tanks continuous flow.

7983. We are quite agreed on the normal condition of things; the average daily flow is 700,000 gallons?—No, the average daily flow is not 700,000 gallons.

7984. Here is your own statement:—"The dry weather flow of sewage into the works is between 600,000 and 700,000 gallons per day"?—Which I have already explained to mean that the average quantity of sewage which comes over our filters and which is treated exactly in precipitation tanks is 700,000 gallons.

7985. You treat some in the tanks?—The difference between that and the 1¼ million gallons, and that accounts for the dry weather flow and the storm overflow.

7986. You produce 526 tons of sludge per week out of 1¼ million gallons daily flow of sewage?—That is so.

7987. That is a heavy production of sludge?—That may be so, but as matter of fact that is a correct statement.

7988. What would that be, say, with a place like Manchester, where they have 25 million gallons a day; if you take it roughly at 500 tons per 1,000,000 gallons?—Well, they would practically have 20 times as much, a little over 20 times as much.

7989. That is a huge amount to deal with?—Well, they must deal with their sludge in some other manner. The calculations got out were for precipitation and dealing with the sludge.

7990. The point I want to get out is this: by your system there is such a heavy production of sludge that the system would only be applicable in districts where sludge can readily be disposed of, either shipped and emptied out at sea or where you have an agricultural population which believes in the utility of this sludge and takes it away?—Yes, that is so.

(*Professor Ramsay.*) Or by distillation, surely?

7991. (*Colonel Harding.*) Or if you can show that it is practicable to distil it so as to produce gas?—That is so.

7992. But unless some rapid means of dealing with the huge quantity of sludge can be found in a locality your system of sewage treatment would not be applicable?—I do not see that at all.

7993. Well, if you take, for instance, a place like Leeds, with 20,000,000 gallons a day normal flow, there would be an immense production of sludge?—Yes.

7994. And it would be almost impracticable to deal with the sludge which would be produced?—Yes, but you have got to determine how you are to deal with your clinker-cum-sludge at Leeds; you have only tried it for a limited period.

7995. How clinker-cum-sludge?—I understand at Leeds you are sending your crude sewage over clinkers.

7996. That is not the point we are on. What I am driving at is how far the successful sewage treatment which you appear to be carrying out at Chorley is applicable to a place like Manchester or Leeds, and I see that it involves the production of a huge amount of sludge?—Yes.

7997. And I see at Manchester they get rid of their sludge by taking it out to sea at considerable cost; and the production of sludge at Leeds, although considerable, is not anything like so considerable as by your plan, and yet involves great difficulty; therefore I suggest to you that it is only in cases where sludge can be readily disposed of that the example you give us of Chorley can be followed?—As a matter of fact, there is a large proportion of sludge at Chorley, but in order to press that sludge we only added per day last year 13cwt. 1qr. and 10lbs. of precipitant. Now, the sludge has got to be dealt with in any system. The only extraneous matter we have in our sludge is the amount of precipitant we put in it. How are you going to deal with the sludge in other places? Take the Burnley case; first and second contact beds.

7998. I think we are drifting a little bit from what I wanted to get at. Your system is thorough and absolute settlement of the solids by quiescent settlement?—Yes.

7999. Well, necessarily, that involves a larger production of sludge than the continuous flow and precipitation which is in use in other places?—I do not admit that.

8000. Then you do not admit the superiority of your system?—No, that is not so.

8001. Your reason for quiescent settlement was to

obtain more complete settlement?—Exactly, but may I illustrate what I mean? Suppose you are out to afternoon tea, and the lady of the house hands you a cup of tea into which she places a piece of sugar, and you do not take sugar; which would you consider the best means of getting out the sugar—taking out the lump before it was properly dissolved or stirring your tea till it was dissolved and then taking it out?

8002. Forgive me if I do not attempt to answer your question?—This seems to me to illustrate the position; there is a certain amount of sludge in every effluent.

8003. I am afraid I cannot be sufficiently lucid to make you understand what I mean; it may be my fault? —I quite understand you.

8004. (*Sir Michael Foster.*) Can we not make the distinction between solids and sludge? You are speaking of solids; Colonel Harding is speaking of sludge.

8005. (*Colonel Harding.*) You have quiescent settlement because you can throw down by such quiescent settlement more of your solids than you can by continuous flow?—Which contains the same amount of solids.

8006-7. Obviously by your quiescent settlement you obtain a larger amount of sludge?—Yes.

8008. Your system involves necessarily a large production of sludge?—At the beginning, only at the beginning; the sludge is there all the same, however you treat it, and although I take my sludge out at the beginning and deal with it effectually, your sludge goes on and deposits itself somewhere and has to be dealt with afterwards.

8009. That may be, but it may not have to be dealt with as sludge?—Yes, but you see it raises the whole question as to the destroying possibilities of the bacteria.

8010. Well, I did not intend to raise this point?—It does raise the question.

8011. But it raises this question: you can deal with the solids in the septic tank. There may or may not be digestion of part of these solids?—As a matter of fact, they have an open septic tank at Burnley, first and second contact beds there; you can see the sludge walking over the sill at Burnley if you have been there. I think the Commission have been there; you can see it going out.

8012. You can see solid matters coming out?—You can see solid matters coming out. In addition to that a certain proportion of solid matter settles at the bottom of the tank, and has to be dealt with every three months.

8013. Well, all that is agreed to; you must necessarily have more sludge by your thorough settlement than where the settlement is less perfect?—We have undoubtedly more sludge at the beginning.

8014. Than where the settlement is less perfect?—We have undoubtedly more sludge at the beginning.

8015. Than where the settlement is less perfect?—Yes, exactly where the settlement is less perfect; but we should contend if it were a question of pounds, shillings, and pence that the amount of sludge which creeps over the sill and is treated in first and second contact beds is more expensive than at Chorley.

8016. It would have to be treated not as sludge?—It would have to be taken out and the filter renewed—infinitely more expensive.

8017. You are assuming there would be no consumption of the sludge by the bacterial process?—The experiments made at Leeds proved conclusively first and second contact beds proved complete——

8018. We are talking of septic tanks?—The one is the natural corollary of the other.

8019. It is alleged that there is a consumption of solids to some extent in septic tanks?—Probably there may be, but it is to a very small extent.

8020. In your system you do not attempt to consume the solids, you remove them before the septic action is begun, and, therefore, there is no consumption of that kind; therefore you have a large production of sludge, which large production of sludge is swollen besides by the chemicals you put into it?—That is so.

8021. Now we are coming back to what I said, that you have a large production of sludge by your system? —That is admitted.

8022. Therefore that system is only applicable where such sludge can be readily disposed of?—No, I do not admit that.

8023. Well, I will not press that further. I do not understand how you get at this amount of sludge. You are quite satisfied you have 526 tons of sludge a week? —Absolutely. That is worked on the hypothesis that that sludge contains 90 per cent. of water. I think, as matter of fact, it contains about 92.

8024. You are not far wrong in your typical analysis you give us of your crude sewage. You said the suspended solids vary from 10·00 to 25·00 per gallon?—Yes, this information was supplied to me by the Chief Inspector of the Ribble Watershed Committee. I cannot verify it. I am not a chemist or analyst.

8025. Which of these figures is wrong—10·00 to 25·00 grains per gallon, or 526 tons a week, because the two do not harmonise at all?—As matter of fact, the 526 tons a week is measured.

8026. You have confidence in that?—That is an absolute fact.

8027-36. (*Professor Ramsay.*) I have been taking the sludge as 525 tons, 90 per cent. water, which gives 52·5 of dry sludge per week, I think?—Seven and a half tons per day.

8037. I am taking it in the week?—Yes, that is so.

8038. Each ton gives 7,000 cubic feet of gas?—Each ton does not. This 7½ tons is 7½ tons of, comparatively speaking, dry sludge, but it contains 50 per cent. of water, you see, after you have pressed it; after you have taken 90 per cent. of water out of it it will contain, at any rate, from 40 to 50 per cent. of water.

8039. That is not mentioned. Halve the figures. I will read them as they stand, then we can divide by two afterwards. It would give 367,500 cubic feet of gas; taking that gas at 2s. per 1,000 cub. ft., it would yield a profit of £36 7s. per week, supposing the gas cost nothing to make, that is, paying nothing for the coal to distil the sludge, and not paying for drying the sludge, or £1,890 4s. a year. We will assume that we halve the figures in order to allow for the extra half of water; that means about £900 as the value of the gas, not allowing for the making. The total cost per head of the population is £1,373 per year, so that you very largely reduce the cost of disposing of the sewage in selling your gas?—That has been my opinion from the beginning, and although it has been suggested, I do not pay very much attenton to the chemist. I believe —yes, I believe it very probable that in the next fifty years, although sewage works may not be a source of income quite to a governing body, they certainly will be a cause of very much less expenditure.

8040. (*Colonel Harding.*) There is no doubt if you can show that gas can be profitably made out of the sludge it would be an argument in favour of chemical precipitation, notwithstanding the huge amount of sludge which is so produced?—Undoubtedly. I was going to say on our precipitation tanks we get an enormous amount of fat. Well, we have carbonised these scrapings from the side of the tanks, and we can get double the amount; we can get 14,000 or 15,000 cubic feet of gas from them. Take the enormous amount of soap which is used in every locality every day. My own opinion is that some day the chemist will recover the soap. I know they do it in Holt Town in Manchester.

8041. (*Chairman.*) There is just one question I wanted to ask you about the amount of the solids that you get out of your sewage by precipitation. You do not claim, I suppose, to get them all out?—Well, in our effluent; in our filter effluent.

8042. Well, your effluent as it is after you have treated it with your chemicals?—Do you mean the tank effluent or your filter effluent?

8043. The tank effluent?—No; we do not claim to absolutely get all the solids out, but you could hardly estimate the quantity of solids left.

8044. I was very much struck by this, that apparently your filters choke so that they have to be cleaned once a week?—Yes.

8045. Well, that means that there must be a certain amount of solids left?—I take it that a certain portion of the solids are in solution and not in suspension, the solution which is effected when it touches the filter.

8046. Do you mean that they go out of solution into suspension?—Yes. I do not know it, but I think it.

8047. (*Professor Ramsay.*) I think you are right?—

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Of course, the water as it leaves the precipitation tank, and I am sorry I did not bring examples of it, is of a milky character. If I were to put in a bottle of filter effluent on the box and a bottle of spring water, it would be impossible to know which was which. We have twice during the last year reduced the organic impurity in our sewage effluent to below the standard of Preston drinking water.

THIRTIETH DAY.

Thursday, 7th March, 1901.

PRESENT:

The Right Hon. The EARL OF IDDESLEIGH (*Chairman*) *presiding.*

Sir MICHAEL FOSTER, K.C.B., M.P., F.R.S.
Major-General CONSTANTINE PHIPPS CAREY, R.E.
Mr. W. H. POWER, F.R.S..
Professor WILLIAM RAMSAY, F.R.S.
Mr. T. W. KILLICK.
Colonel HARDING.
Dr. J. BURN RUSSELL.

Mr. F. J. WILLIS, *Secretary.*

PRESENT ALSO:

Dr. G. McGOWAN.
Professor BOYCE.
Mr. COLIN C. FRYE.

Mr. ENOCH GEORGE MAWBEY, called; and Examined.

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8048. (*Chairman.*) I believe you are the Borough Engineer of Leicester?—Yes, my lord.

8049. I think you have acted as chief engineer for the sewage disposal works of the Corporation?—I have.

8050. And you have carried out some rather extensive experiments in the bacterial purification of sewage?—Yes, I have.

8051. What is the total population of the borough?—220,000.

8052. And what is the volume of the daily dry weather flow of the sewage?—Seven and two-third million gallons. That equals about 39 gallons per head per day.

8053. And what is the nature of the trade refuse that you have to deal with?—The foul trade water comes chiefly from dyeworks and wool scouring and fellmongers' and curriers' places. The chemical condition of the sewage has always been found slightly alkaline.

8054. Do the manufacturers treat their liquids in any way before passing them into the sewers?—No, except by ordinary catch pits and gratings.

8055. Now about that catch pit: Does the catch pit act as a settling tank?—It does.

8056. And the solids remain in it?—Yes.

8057. (*Sir Michael Foster.*) How big are the catch pits?—Oh, they vary according to the size of the place, Sir Michael—about 10ft. square, something like that, and about 5ft. or 6ft. deep.

8058. (*Chairman.*) When you say that the manufacturers do not treat their liquid except in this way it does come in for a considerable amount of treatment, because the solids are either kept back by the gratings or by the catch pits?—Yes, there are a certain amount of solids, but what we find, unfortunately, is that they work these tanks so long without clearing them out that we get a great deal of solids washed out into the sewers. They run them until they are overflowing with sludge, especially from the fellmongers' place, and we have several times had to go and clean out the sewers of the solid matters getting beyond the catch pit.

8059. (*Sir Michael Foster.*) Blocking the sewer?—Well, at the fellmongers' they certainly did block the sewer several times. It was only a small sewer, though.

8060. (*Mr. Power.*) And they discharge their refuse at intervals into the sewers, not continuously, I suppose—the manufacturers?—They do so; they just run it into these catch pits as it might be in the middle here, and run through continuously, as they produce the liquid.

8061. (*Mr. Killick.*) Do you take in your fellmongers' effluents at Leicester?—We do, but there is very little. There is not very much, sir. Might I say that the whole of what you would call dense trade liquids from these different mentioned trades amount, I find, to about half a million gallons a day. You will see that I say the trade water of the whole of the borough is 2,000,000 gallons a day, but if you take these thick liquids it amounts to about half a million gallons a day.

8062. (*Mr. Power.*) One-fourth of the 2,000,000?—Yes, sir.

8063. (*Chairman.*) Then, is the domestic sewage treated in any way?—Not at all.

8064. The raw sewage goes on to the farm?—Yes; well, it goes into settling tanks at the farm, first small receiving tanks.

8065. It goes on to the settling tanks before it goes on to the land?—Yes.

8066. Then both the trade refuse and the domestic sewage have the solids to a considerable extent eliminated before they go on to the land?—They do.

8067. Then to what extent is the surface and the storm water excluded from the sewers?—A separate system is only partially carried out; at present the surface and the storm water over a very large area of the borough is discharged into the ordinary sewers, but for some years past the new streets have been provided with separate systems, but the surface and the storm water sewers are mostly at present connected to the main foul water sewers as a temporary measure until the system of intercepting surface and storm water sewers is provided, so that you do not get the full benefit you see of the surface and the storm water system.

8068. (*Mr. Power.*) The storm sewers have overflows, have they, into the streams?—Yes, they have.

8069. At what point do these overflows come into operation?—At what point of volume, do you mean?

8070. Yes; in the storm-water sewers which have storm overflows before they join the main sewers?—At the pumping station; first of all, I must explain that the whole of the sewage gravitates to a pumping station. You will see in the evidence there is an exception of a certain amount of the population, but taking the bulk of the town, it gravitates to a pumping station. Well, now, at this pumping station immediately before reaching the pumps, there is a big storm-overflow chamber, and at this chamber there is an overflow weir, and on the low side of this weir there is a culvert 8ft. in diameter running 3¾ miles down the valley to a point where it can get a free outfall into the river. We pump and treat, roughly, I should say, about double the dry weather flow.

8071. About double the dry weather flow?—Yes, sir, about that.

8072. And anything in excess of that you pass away by the storm overflows?—Yes, but there are local overflows for great storms on the system at points you know on the river and canal; but that is not your point, is it?

8073. Yes, I wanted to know about those, too?—About those, too?

8074. Yes?—Well, those do not come into operation until the rainfall increases the dry weather flow to such an extent as equals a rainfall of 2in. in 24 hours. That is to say, that after the rainfall exceeds the rate of 2in. in 24 hours these local overflows come into play.

8075. That rate of flow?—At that rate of flow.

8076. And a sudden and heavy, but short, downfall would bring them into operation much sooner than a steady and continuous downfall?—Exactly.

8077. (*Major-General Carey.*) What dilution would that represent?—About 12 to 16 times, sir, before these locals come in.

8078. Before the overflow came into operation?—Yes, those local ones.

8079. (*Sir Michael Foster.*) How often do they come into operation, would you say; I mean how many times in the year do you think they come into operation?—They vary from five or six times to perhaps a dozen, according to the rainfall of the year—something like that.

8080. A very heavy rainfall year they would come into operation about a dozen times?—Yes, they would quite.

8081. (*Chairman.*) What is the area of the land you use?—1,355 acres we use for irrigation, the total area of the farm is 1,700 acres, and the difference of 345 acres is used for grazing purposes when the stock cannot all be accommodated on the sewage land.

8082. Then those 345 acres never come under sewage treatment at all?—They do not.

8083. Have you ever found any nuisance from the sewage on the land?—We found in some times of the year a very offensive smell from the area.

8084. A very offensive smell?—Yes. You see the reason is this, that although, as I said, a good deal of the solids are precipitated before it goes on to the land, you quite understand that as these precipitation tanks, ordinary settling tanks, only have a capacity of 600,000 gallons out of 7⅝ million gallons, that a great deal of the solid matter—at any rate, the organic solid matter—goes on to the land, and it sludges up the area a great deal, and at times of the year it is offensive; but it is a very isolated place, fortunately, so that we have no serious trouble, except that people complain a little sometimes, but nothing serious.

8085. You do not know any case where it has been injurious to health?—We have had no such case.

8086. And you have never had any case where the stock suffered from it?—No. The only thing we have ever had happen on the farm, so far as I know, is some anthrax cases; but, of course, that had nothing to do with it; our stock do wonderfully well. We have sometimes a thousand head of bullocks on the farm, and we never have less than 500 or 600 head, and they do remarkably well there; they are quite a picture—the cattle

8087. Do you have milk cows there?—No, we do not.

8088. (*Mr. Power.*) Do bullocks get access for drinking purposes to the grips carrying the sewage on the farm?—They did, sir, when we first started for several years; until we got some additional land they used to graze regularly with the sewage flowing on the land.

8089. Flowing over the surface?—Over the surface; that is on the old pasture, of course; it is true it was the second application, the first application of the sewage crude having gone over arable land.

8090. It had been taken up and distributed over the pasture land; it was the second application to land?—Yes, it was the second and third, and it was there they grazed a good deal, too. The only difficulty we found was that they poached up the land so much, we keep them off all we can; nevertheless, they do graze now during the operations.

8091. (*Chairman.*) Then is the sewage from the whole population dealt with on those 1,355 acres?—The population of about 197,000, together with the trade water, is now treated on that land, and the sewage from the remaining 23,000 population is dealt with at two other small farms.

8092. But you have had experience of land treatment of sewage?—Yes.

8093. And you would say positively that in your opinion it produces no injury to the health either of human beings or stock?—I think not.

8094. Then what is the nature of your soil?—With the exception of thirty acres of it, it is clay under the top soil, which is about six inches to a foot thick. There is a layer of stiff yellow clay about two to three feet deep overlying blue boulder clay for a great depth.

8095. And have you prepared and drained the land?—Yes. The way we prepared it was this: first of all the ordinary ditches were widened and deepened, to serve as the main effluent drains leading to the natural watercourses, and the drains of each field has its own separate outfall, which is brought out on to the surface of the lower field, and arranged so that the foul effluent that always reaches the drains of a clay farm can be treated a second or a third time on other land as may be found necessary to effect a sufficient purification. A surface effluent can always be treated on successive areas until fit to send into the streams. In the old orthodox way of irrigation, that is. The top land which adjoins the sewage carriers is all arable. There is 453 acres of that, part of which has been broken up from old pasture. The crude sewage is first discharged on to this arable land and finished off on the old pasture or rye grass. The lower fields, which were originally arable, have been seeded down, and the total area of the pasture land is 902 acres. By this means the drawbacks of a clay farm are very largely overcome. I should like to say one more word about that. I have had something to do with clay land before, and I have always found that if you do drain it in the ordinary way, as there is only a small depth of humus, you do not get sufficient filtration, and it finds its way down into these drains (not having got its six or seven feet for filtration) in a foul condition. We expected the same failure at Leicester. It was prophesied that we should fail because of that. Some said, "Well, you must not drain the land." Well, we tried that for a little while, and we found that we could not possibly get the horses on. We have had to wait from twelve to twenty weeks before we could get the horses on to plough after sewaging; we found that we must drain it, and we got over it in this way, but it was after a great deal of study. The farm, fortunately for us, has good slopes, so that pumping the sewage on to the top of the watershed, part of it falls down to one valley and part to another, and the idea I conceived was that, instead of having an arterial system of drains and connected up to the main drains, so that when you put the sewage on to a top field it would pass through only six inches to a foot of soil, into the system, which was as good as into the river at once; instead of doing that, I have laid a main drain along the bottom of each field to the lowest corner, and taking advantage of the superior slope of the farm, getting it out to the surface of the next field below as quickly as possible, and dealing with each field the same; so that the foul effluent which gets into the drain at one field is thrown over the surface of the next, and on the next again, if not fit to send away, and when it is fit to send away, we can drop it into any of these dykes, let it go away through the ordinary natural drains of the land, or bring it on to the surface of the land again, and in that way we achieved a very great success.

8096. (*Major-General Carey.*) They were intercepting drains?—Exactly.

8097. (*Mr. Power.*) To what depth do you think the sewage penetrates into the soil, say the arable land, at Leicester. The difficulty is that in the first instance I suppose it was held up by the clay at a very short distance from the surface?—Yes, that was so.

8098. Within how many inches should you say?—The bulk of it was held up within a foot, but of course it would gradually permeate through a couple or three feet more, but extremely slowly, not sufficiently.

8099. The difficulty in dealing with the land was that the sewage was held up by the clay?—And then it concentrated itself over the trenches naturally, and there found its way into the drains. Always in hot weather, after rest of the land, we had the fissures in the clay to deal with, and it used to run through these and get quickly down that way.

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8099*. (*Chairman.*) Of course there is clay land and clay land. Do you call your clay very stiff?—It is very stiff.

8100. It is very stiff?—Yes. It has a very large amount of alumina in it. It is stiff yellow clay, this top 2 feet under the humus, and then boulder clay, and that particular boulder clay is a blue heavy solid clay, that is very close. It is interspersed truly with drift chalk, flint stones, and that sort of thing, but it is more like a concrete than anything else.

8101. You call it very stiff, do you?—Very stiff.

8102. You are fortunate, of course, in the lie of your ground, I mean your slope is fortunate for you?—That is the great thing that saved us.

8103. (*Major-General Carey.*) The purification was really taken by a triple filtration?—It is so, and triple or double surface irrigation now.

8104. Through this medium of soil?—Yes.

8105. And your farm was favourably situated for that purpose?—Exactly so. You get a sort of double contact by means of the drains and double contact by means of surface irrigation and frequently treble contact in both cases.

8106. (*Sir Michael Foster.*) By "other land" you mean additional land, you do not mean land of another kind. At the bottom of the first page of your notes it reads as if it meant other than clay land, but all your land is clay land?—Oh, yes, it is so.

8107. You say "the clay sewage farm on other land." You do not mean land of another kind, you mean additional land?—Oh, yes, exactly so, additional clay land.

8108. How do you judge with your intercepting drains whether you should drain it on the surface again, or let it go into the main drains?—Our watermen now are very expert in that way. Of course there is a rule of this sort, that they must never send it away until it has had two applications, and they judge then whether it needs a third.

8109. By experience?—Yes, sir; but we have a regular analysis made—a series.

8109*. (*Chairman.*) Would you mind defining broad irrigation before we go any further?—Yes, my lord. The sewage flows along the top of the watershed of the farm in a feeder, and then it flows into distributing grips and contours, so that the intention is that the work shall be done mainly by flowing over the surface as contrary to vertical filtration.

8110. Then, could you tell us to what extent the broad irrigation on your clay land has been successful in purifying the sewage?—For several years effluents were uniformly satisfactory, and quite equal to acknowledged satisfactory standards. The following analysis taken in October and December, 1891, namely, 12 to 15 months after the farm had been in operation, is a fair average:—

Albuminoid ammonia, ·09 grain per gallon,
and
Oxygen absorbed, ·562 grain per gallon.

8111. (*Mr. Power.*) That was with treble filtration in effect; was it after it had gone through three plots?—It was partly double and partly treble. I might explain that, sir. If the plots were very large, that is to say, if the plots we were using were long ones, two of them would do, but if we had a section of the farm where there were shorter plots and smaller, and it did not have to travel so far, we would have to send it over three.

8112. (*Colonel Harding.*) At that time that you were getting those good results, how many people to the acre?—At that time we had 114 persons to the acre, the maximum, but it has now reached 145 persons per acre, and 7,000 pail closets have been rapidly converted into water closets, it is proposed to pump the sewage from an added area to this farm, which would bring the total population up to 154 per acre, and the total dry weather flow to about 8,000,000 gallons per day. This extra burden on the farm, and the consequent deterioration of the quality of the effluent made it necessary either to very largely increase the area of the farm or adopt some very efficient means of preliminary clarification. I advised that bacteriological experiments in the purification of the Leicester sewage on a sufficiently large and practical scale be carried out.

8113. (*Chairman.*) Now before we come to the experiments at all, I should just like to ask you about your balance-sheet. Did the farm pay its expenses?—No, my Lord, there was a very great loss.

8114. A very great loss?—Yes. thousands a year.

8115. One thousand pounds a year?—Several thousands a year.

8116. On a farm of 1,700 acres you made a loss of several thousands a year?—We made a loss of £6.000 or £7,000 a year, that is taking everything into consideration.

8117. No doubt you worked it in a very thorough and scientific manner?—I think that is the reason, my lord, we do. I started by saying that their first duty was to purify the sewage, and they made me master of the agricultural operations as well as the engineering for a year or two, until we got into first rate form, and then they allowed the bailiff to manage the sewage himself, subject, of course, to my advising them as their engineer; but we have got an admirable committee, and they always have cleansed the sewage first, and then done the best they could with the land and the crops afterwards.

8118. I suppose you would say that if you have a sewage farm you must have some skilled person to manage it if the sewage is to be properly treated?—Certainly, we have a very good man.

8119. I mean that an ordinary farmer could not farm a sewage farm so as to treat the sewage properly?—Certainly not. The worst man you could have would be an ordinary farmer.

8120. (*Major-General Carey.*) Has the farm ever been managed by a tenant not employed by the Corporation?—No, sir.

8121. (*Professor Ramsay.*) Would you say that the reason that a farmer is a bad manager of a sewage farm is that his interest lies in producing crops and not disposing of the sewage?—Yes, there are many times in the year when he does not want the sewage, and if he can shoot it into the watercourse he will.

8122. (*Colonel Harding.*) You have given as a typical analysis the farm working, with 114 to the acre; do you attribute the deterioration entirely to the overworking?—Yes.

8123. If the population had not increased would there have been deterioration from the increasing age of the farm?—Well, I do not think there would have been deterioration. I am bound to say that the land has slightly improved. Members of our Committee say it is immensely improved. I do not quite go so far as that because, as I say, you can only improve it to the depth that you can plough it and cultivate it, but it has not deteriorated; it is friable at the surface, and it dries off a little quicker, and it is the more efficient of the two, but the increase of the population and the converting of the pail closets into water closets has brought too great a burden upon the farm, with the result that for the last year or two the albuminoid ammonia went up from ·09 grains per gallon to ·3025, and the oxygen absorbed from ·562 up to 1·0538.

8124. (*Mr. Power.*) Was there corresponding increase in the strength of the raw sewage—have you any figures for that at the one time and the other?—No, there was not, sir. It averaged about the same. Of course these are just good average samples of many months' working, and it does not vary much if you take a sufficient period, which we always do.

8125. The raw sewage you are speaking of?—Yes, sir. Might I just show you this: this is a diagram I had made to show the albuminoid ammonia and oxygen absorbed. I started with an idea of a standard, that is one-tenth of a grain per gallon for the albuminoid ammonia and a grain per gallon for the oxygen absorbed. If you take the albuminoid ammonia in 1891 when the land was not overworked, the average for a good many analyses is ·09 grains per gallon of albuminoid ammonia, that corresponds with that table. The average in 1891 for oxygen absorbed is ·562. Well, then, in 1896 it got up, you see, the albuminoid ammonia to ·3592, and the oxygen absorbed up to 1·0903 grains per gallon. Then we had another batch in 1898 which seems to require explanation, because this, you see, was later when the farm was more worked, and then it was ·30 grain per gallon instead of ·35, and the oxygen absorbed 1·05 against 1·09. But you have it just as we took it. We had a great many samples. For some reason or other, whether it was that the land was in better condition, or the weather was better for us—for the operations—I do not know, but I thought you had better have the truth of it. But, however, you see it had got up so high that I strongly advised the Committee to do something, and I told them I thought it would be very much better to endeavour to clarify the sewage bacteriologically than

to increase the area of a farm which is already a big undertaking. Well, now, the main processes that we have carried out are No. 7, No. 14, and No. 17.

8126. Will you tell us what, under such circumstances, were the chief objects of these experiments?—The chief objects of these experiments were (1) to enable me to determine by what process the sewage could be the most efficiently clarified before applying it by broad irrigation to pasture land and to ryegrass for final purification without seriously fouling the crops. Such clarification process to also effect as much purification as possible, as indicated by reduction of albuminoid ammonia and in oxygen absorbed, and to produce the least practicable amount of sludge. (2) To prove whether the sewage could be satisfactorily purified without any application to land and so render it unnecessary to carry into effect the contemplated purchase of the farm, which with the exception of 100 acres is leasehold or otherwise rented or to completely treat a portion of the sewage for the purpose of relieving the land.

8127. (*Sir Michael Foster.*) Do I understand in your diagram there that the blue which has nothing shaded is the percentage in the crude sewage, and where it is shaded is the percentage in the effluent?—Oh yes, exactly, the final effluent. That is what we got when we made up our minds that we must either increase the area of the farm or adopt some system of clarification, but I will leave these processes until you ask me for them.

(*Chairman.*) I suppose you never made any bacteriological analyses?—We have not.

8128. Then you advise that bacteriological experiments should be carried out, and would you tell us what your chief objects in those experiments were?—The chief objects of these experiments were several: (1) To enable me to determine by what process the sewage could be the most efficiently clarified before applying it by broad irrigation to pasture land and to rye-grass for final purification, without seriously fouling the crops. Such clarification process to also effect as much purification as possible, as indicated by reduction of albuminoid ammonia, and in oxygen absorbed, and to produce the least practicable amount of sludge; (2) To prove whether the sewage could be satisfactorily purified without any application to land, and so render it unnecessary to carry into effect the contemplated purchase of the farm which, with the exception of 100 acres, is leasehold or otherwise rented, or to completely treat a portion of the sewage for the purpose of relieving the land.

8129. Does the farm belong to you?—100 acres of it belongs to us, but the remainder is leasehold, and we have 16 years to run, and as these experiments have proved so satisfactory for preliminary clarification purposes I advised them to buy the farm, at least to buy 1,200 acres of it, and retain it for final purification, in preference to abandoning the farm, and going in for complete bacterial treatment. They have adopted that course, and the arbitration will be in process directly for acquiring it.

8130. You have bought the farm?—Practically, yes; we are waiting for the arbitration to come on—we are going to have it; we are bound to have it now.

8131. Then would you describe your experimental plant?—I do not think I have a cartoon for that, but if any gentleman has the book—the report—he will be able to follow it from the map. I have one, sir.

8132. Will you shortly describe your experimental plant?—The experimental plant consisted of (1) a channel and weir chamber 20ft. long by 4ft. wide, for delivering and measuring the crude sewage; (2) A detritus tank 30ft. long by 15ft. wide by 7ft. deep in the centre, having a water capacity of 18,681 gallons; (3) A second tank adjoining the latter, 130ft. long by 30ft. wide, averaging 6ft. deep at the inlet end and 4ft. 3in. deep at the outlet end, with sludge channel below these levels, and having a total water capacity of 125,962 gallons. Both these were used as open tanks in the early experiments, but were afterwards closed for other experiments.

8133. I wanted just to ask you, why do you call it a "detritus tank"? Do you distinguish between the two tanks in any way?—Yes.

8134. Is there any reason why you should not call them a first and a second tank?—I do not think there is any reason excepting that I wanted the first tank to be only for these experiments, sufficient to make sure that I get all the mineral matter down; then the second tank, I wanted to act for a further subsidence of lighter organic sludge, in the first place open, and then when I closed it to work on septic principles entirely, the mineral matter having been taken out.

8135. Quite so. Then your object was to get a small tank in the first instance, which would catch the minerals?—Exactly.

8136. And which would be easy to clean out?—Exactly—that is it. Then there are four first contact clarifying bacteria beds filled with clinkers from our refuse destructors. The clinkers in two of these beds passed through a crushing machine with jaws set to a 2½in. gauge, and this crushed material was stopped by a 1½in. meshed screen. In the other two beds the clinkers passed through a crushing machine with jaws set to a 1½in. gauge, and this material was stopped by a ⅝in. meshed screen. The average depth of the clinker in the beds was 4ft. 6in. The total clinker and water capacity was 740 cubic yards, or a mean superficial area of about 500 yards.

8137. (*Colonel Harding.*) Of the whole?—Of the whole four, yes. There were also two second contact clarifying bacteria beds. One of these beds was filled with crushed and screened destructor clinkers. This material was passed through a ½in. meshed screen, and rejected by a ⅛in. meshed screen. The other bed was filled with a mixture of burnt clay ballast, and destructor clinker, varying in size from half an inch to one-sixteenth of an inch. The depth of the material in these beds was 3ft. In connection with these experiments a total area of 25½ acres of land was used for the final purification of the effluent. Of this area 13½ acres were old pasture and 12 acres were rye-grass.

8138. (*Chairman.*) After it had been through your artificial tanks and contact beds you do not put it on to arable land at all?—Not at all.

8139. Did you bring it out at the bottom of your slope, or where?—At the bottom.

8140. At the bottom of the slope?—At the bottom of the tanks.

8141. No; you showed us your land ran in three fields?—Yes.

8142. I wanted to know whether you brought it out on a slope, so that it ran down, or whether you brought it out on to level land?—I brought it out on to a slope.

8143. To a grass slope?—To a grass slope.

8144. (*Sir Michael Foster.*) You are making now the ridge on your farm?—It was a piece of land about two-thirds down the slope of the farm. But it did come out of the tanks on to lower sloping ground.

8145. (*Major-General Carey.*) What volume of sewage did you put through the tanks?—I will answer that later on if you will kindly allow me.

8146. (*Chairman.*) Then you tried experiments with both tanks open, then one tank open and another closed, and then both closed?—Yes.

8147. And without sending it through any filter beds at all?—Yes.

8148. Then you tried various things both with the tanks and with the contact beds?—We did, yes. Would it help you if I was to give you a minute or two on that cartoon just to explain the different processes, do you think?

8149. (*Colonel Harding.*) Before you pass on would you give us the area of the second beds?—They were 150 square yards the two.

8150. Together 150 square yards?—Yes, sir.

8151. (*Chairman.*) If you would perhaps give us a general statement of the results of the different processes with the help of those diagrams?—Yes, my lord.

8152. (*Major-General Carey.*) I think it would be better if you would answer my question; that will give us the whole thing?—The detritus tanks we used first open, and the volume treated in the detritus tank per day averaged about 8 to 9 times its capacity, and then when it was used closed it varied from 7½ up to 20 times its capacity, and when that big second tank was used as an open tank it was treated at the rate of its own capacity, that is to say, the volume treated through it per day equalled its total capacity.

8153. (*Colonel Harding.*) Was that the uniform rate whenever you used it as a septic tank?—Yes, that was when it was open, but now I am coming to when it was a closed septic tank. We then treated 1¼ times its volume per day at an uniform rate as a septic tank.

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8154. Did you flow effluent through it when you worked it as a septic tank?—We did a little, sir; that is the long settling tank, when it was used as an ordinary open it was treated at about the volume equal to its own capacity, and as a closed septic at 1¼ times its capacity.

8155. Then how did you prevent septic conditions arising when it was open, and you flowed through it at that rate?—Septic conditions did arise.

8156. Then it was merely an open septic tank?—It was.

8157. Will you describe the different experiments you have carried out?—Altogether 17 experiments or processes were tried. Group 1.—Process 1: Open detritus tank, open subsidence tank, and broad irrigation on old pasture. Process 2: Closed detritus tank, open subsidence tank, and broad irrigation on old pasture. Processes 10, 11, 12, and 13.—Closed detritus tank, closed septic tank, and broad irrigation on old pasture or rye-grass. Group 2.—Process 5: Open detritus tank, open subsidence tank, first contact bacteria beds, three fillings a day and broad irrigation on old pasture. Process 6: The same as process 5, but with the detritus tank closed. Process 7: Closed detritus tank, first contact bacteria beds three a day and broad irrigation on old pasture. Process 9: The same as No. 7, except that the bacteria beds were filled four times a day. Process 8: Closed detritus tank, closed septic tank, first contact bacteria beds, three fillings a day, and broad irrigation on rye-grass. Group 3.—(Closed tanks and complete bacterial treatment without land). Process 14: Closed detritus tanks, first and second contact bacteria beds three fillings a day. Process 17: The same as No. 14, except that the third contact bacteria bed was used, and all the bacteria beds were filled four times a day. Process 15: Closed detritus tank, closed septic tank, first and second contact bacteria beds, three fillings a day. Process 16. The same as No. 15, except that the third contact bacteria bed was used. I should like to place on record that the whole of the analyses were made for me by Mr. S. F. Burford, F.C.S., of Leicester.

8158. To what extent do you propose to deal with these processes in your evidence?—I should like to give you some information about each of them, dealing fully with the most important ones, and only very briefly with the remainder.

8159. Will you take them then in the same order as already classified, proceeding with Process 1 of the first group?—It would be a great advantage if we ran straight through them. I think if you will allow me to say so, these experiments consisted of three broad systems. One group of experiments were carried out with open and closed tanks and broad irrigation, and then the next group of experiments, Group No. 2, were open and closed tanks, and first contact bacteria beds, and broad irrigation, and the third group were closed tanks including septic you know, and complete bacterial treatment without land.

8160. (*Mr. Power.*) Double contact, you mean by "complete bacterial treatment"?—Yes, and there was treble contact as well, sir, that is going on with the chairman's next question, as to what extent I propose to deal with them. I thought I should like to give you some little information about each of them, but dealing only fully with the most important ones. Then, sir, if you ask me question No. 19 I should like to say that this process No. 1 was putting the sewage through an open detritus tank and then through another subsidence tank, and then finishing off on old pasture.

8161. (*Colonel Harding.*) Now, was this treating septic effluent upon old pasture?—The next one is.

8162. But the one you were speaking of?—No.

8163. How is it, it was not septic, was the speed faster than you have told us. Was it simply subsidence followed by land treatment?—It was.

8164. Without septic development?—Yes, to any great extent.

8165. That is in Processes 1 and 2?—Yes.

8166. (*Chairman.*) Process No. 1, as I understand you, put it through two open tanks, and then on to the old pasture?—Yes.

8167. Then was it septic treatment?

8168. (*Colonel Harding.*) The rate would bring about septic treatment, but the experiment was carried out for so short a time that septic conditions would scarcely arise?—This process was continued for 22 days from October 20 to November 10, 1898. The old pasture on which the effluent was treated soon became somewhat fouled, showing that simple open detritus and subsidence tanks do not effect sufficient clarification. Too much sludge was also produced, the amount of which I will deal with later on. Process No. 2 is the same as Process No. 1, except that the detritus tank was closed, and it was continued for 27 days, but the old pasture was still fouled in that process. And then going on to the next Processes, 10, 11, 12, and 13, that is the closed detritus tank and closed septic tank, and broad irrigation on grass land, which is the very important one I want to bring out. That is 10, 11, 12, and 13 of Group 1. In reply to that question, my object was to endeavour to clarify the sewage on the septic system before applying it to the land for final purification, and the sewage was then first passed through the small detritus tank, and then through the septic tank proper—the closed septic tank, and then it was treated by broad irrigation on the land, the area being changed every week.

8169. Now, how long was this process carried on, my object being to ascertain whether really septic conditions had fully developed?—Oh, yes, this was carried on from the 5th June to the 13th October.

8170. Four months?—4½ months.

8171. Were you able to notice in this closed tank how long it was before the septic condition did arise?—Oh, they began in about three weeks, about from a fortnight to three weeks, if it is hot weather they began sooner than in the cold weather.

8172. It would only be in the latter period that you would get the full septic development?—It was offensive in the first three weeks, and it was in a highly septic condition no doubt; we had the full benefit, I do not say the fullest benefit, but we had septic conditions in the first three weeks. But what we found was this, that it was less efficient in the latter period—the septic tank was—than it was in the first half.

8173. In what sense less efficient?—Less efficient in purification, and the results from the bacteria beds where the effluent had gone on were less efficient during the latter part of the period than they were with the earlier part.

8174. We are not talking about bacteria beds now, are we? We are talking about septic effluent on land?—What I mean to say is, that the septic action in the tank was not so efficient at the end of the period as it was in the earlier part—that is, for purification purposes.

8175. In the earlier part septic conditions would have developed to a less extent?—True.

8176. In the later period there would be more active putrefaction?—Yes.

8177. And your estimate of its efficiency is guided by the analyses?—That is so, sir. Certainly if you look at these tables you will find that.

8178. Then are you able to tell us whether the offensiveness in connection with the land treatment of which you had cause to complain was greater at the end of the period than at the beginning?—It was a little greater at the end than at the beginning.

8179. Was it marked?—It was extremely marked at the first time.

8180. Was the offensiveness marked?—I do not think it was very much more marked at the end, but it was extremely offensive right the way from the beginning.

8181. The fact being that what you had put on the land had partly putrefied?—It had very largely putrefied; after the first two or three weeks it was in a terrible state, and it was slightly aggravated towards the end of the period.

8182 (*Professor Ramsay.*) Were the tanks filling up during this process? Was it not possible that the tanks were filling up, and that the daily flow was much more rapid at the end than at the beginning of your experiments?—They were filling up, sir.

8183. (*Colonel Harding.*) The offensiveness would probably be due to the increasing putrefaction?—Yes, it might be.

8184. If you put perfectly fresh sewage on land it does not stink at the moment of being put on the land?—No.

8185. But if you put sewage which has been allowed to putrefy in septic tanks on the land it will distinctly stink?—Yes, and what I would say is this, the more

you work the land the more nuisance on the land. Undoubtedly it was so between the two.

8186. Up to a certain point until you reached the maximum putrefactive condition?—Well, we think we reached the maximum putrefactive condition in 4½ months, and it was, as I say, even offensive at the latter period than at the beginning.

8187. What you want to tell us is that using septic effluent on land—such septic effluent being in a putrefactive condition, you had to complain of serious bad smells?—Yes.

8188. You gave it up for that reason?—What I want to say is this, that in my opinion you cannot treat septic effluent on grass land by broad irrigation without causing a serious nuisance; I also want to say that it takes a vastly greater area of land to purify a putrescent septic effluent than it does to treat fresh sewage. That was our experience, and so we found that instead of that system of clarification getting us out of our trouble of having too little land it would increase our troubles; we should be more likely to want more pasture or rye grass land for broad irrigation if we attempted to clarify by a septic system.

8189. (*Chairman.*) Only just one thing I do not quite understand, and that is an observation that you made. You said the table showed that the percentage of purification on the crude sewage in suspended matters was 55·28 after passing through the closed detritus tank, and 83·01 after passing through the septic tank?—Yes, my lord.

8190. Well, now I understand you say that purification is no use?—No; what I mean to say is this: that in suspended matter there was always an improvement by the septic tank. Always right through, both in suspended matters and in oxygen absorbed and also albuminoid ammonia, there was always an improvement by the septic tank after the detritus tank; but what I mean is that when you put this septic effluent on the land it was so highly offensive that you had to use a greater area of land for a certain volume of sewage by the septic system than you did by the clarifying beds.

8191. Oh, yes; but the clarifying beds are filtration?—Yes.

8192. But did I understand you to say just now in answer to Colonel Harding that you had to use more land for the septic effluent than you did for the crude sewage?—Yes, we did actually that—that is the point.

8193. (*Sir Michael Foster.*) You poured a certain quantity of your crude sewage on a certain area of the land, and what little smell there was very soon went away?—With the crude, yes, sir.

8194. With the crude; but you found when you used the material from the septic tank that if you put the same quantity over the same extent of land it was very offensive; if you put it over a larger quantity of land the smell disappeared fairly rapidly, so that it did not become a nuisance?—Is that the septic?

8195. Yes?—No, unfortunately the nuisance went on everywhere and all over it.

8196. But you said you required more land?—Yes, you do, sir; you require more land to get it purified, but if you start and put the crude sewage on the first plot of land, you will get a small amount of nuisance from crude sewage, put it on the second plot you will not get so much from that; the third plot you will practically get none of it—that is, with crude sewage after it has just passed through an ordinary subsidence tank. Now what happens with the septic effluent? It was extremely offensive on the first, second, and third plots.

8197. You mean using your intercepting drains?—Yes.

8198. On the top of the first plot, and then take it from the top of the second and the top of the third?—It was offensive on all three of them. It was not quite so offensive on the second as the first, not quite so offensive on the third as on the others; but it was still offensive, and what is worst—now in reply to the Chairman—we did not get so much purification out of the land with the septic effluent as we did with the crude effluent.

8199. (*Colonel Harding.*) You did not find the septic or anaerobic treatment as a first process assist the treatment on land at all, or the contrary?—It was the contrary, sir.

8200. (*Chairman.*) There is one question I should like to ask, please. Before you began these experiments, all your sewage, as I understand, went into detritus tanks?—Yes, my lord.

8201. Before it went on to the land?—Yes.

8202. Then it went on to arable land?—Yes.

8203. Then what is the difference between your old detritus tank and these new tanks which you put up when you began your experiments?—There is very little difference. In the first detritus tank it is exactly the same principle, an open tank through part of the experiments, but we afterwards closed it, covered it over. But then, in addition to this first detritus tank, you see we had a long second tank for a second subsidence, and then afterwards we covered that over and turned it into a septic tank proper, so that was the difference between the experiments and the normal treatment of the sewage.

8204. But then you made the sewage go through two tanks instead of one, that is the only difference?—In part of the experiments, yes.

8205. And by making it go through the second tank you made it more offensive than it was?—Certainly, when the tank was under septic conditions, and under cover it, the effluent was more difficult to treat, and I want to emphasise this very much that if you had passed it through the second tank after that tank was made into a septic tank proper you made it possibly more difficult to purify it on the land than you did when you sent it from the first small detritus tank on to the land.

8206. And when it went through the second tank it went through the second tank first when it was open, and afterwards when it was closed?—Yes.

8207. Was it worse when it was closed than when it was open?—Yes, it was.

8208. But even when it was open the second tank had the effect of making it worse?—Yes, Sir, rather more offensive.

8209. (*Sir Michael Foster.*) I understand that the material from your septic tank in the third plot was not only still offensive, but when you examined the effluent from that third plot you found that chemically it was less pure than the effluent from the crude sewage treated in the same way?—It was, Sir.

8210. What difference was there?—You will find that in the tables, Sir, Process 15, I think it was.

8211. (*Chairman.*) I do not see in those experiments that you brought on to the arable land at all your effluent from the septic tank?—No, we did not, my Lord.

8212. Then is the comparison fair?—Well, you see what we want to do now; we want to get rid of this great area of uncropped arable land, because it is so extremely costly to cultivate being clay land, and it is also unproductive—a great area—so our object is to seed down other land, and to be able to clarify the sewage so that then it can go straight on to old pasture or rye grass without having a lot of land uncropped.

8213. It is quite fair to say that the two tanks do not satisfy you, but I do not see how you can compare your crude sewage and your septic effluent if you pass one through arable land and you do not pass the other?—You mean to say that if they had passed the septic effluent through some arable land before it went on to the pasture.

8214. (*Sir Michael Foster.*) If you want to get a comparison you ought to have done with your septic effluent what you did with your crude sewage, if you want to compare the two? The Chairman is right in this respect that when we are treating normally the sewage of the farm we send it over a plot of arable land, and then we send it over one or two plots of pasture after having put it through an ordinary detritus tank. Now you say that in those experiments you sent it from the septic tank straight on to the old pasture without putting it over an arable plot of land?—Yes, but I can carry that a bit further because whenever we are tied up in agricultural operations we often do have to send the crude sewage straight on to grass land. We do not do it if we can help it, but we very often have to do it, and there again we find that it is quicker treated and more effectively treated by sending it straight on to the plots of pasture than it is when you send the septic effluent on to the rye grass or pasture.

8215. (*Major-General Carey.*) And there is no nuisance when it is applied to grass land?—There is just a little nuisance at times with broad irrigation in the ordinary way.

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8216. But not to be compared to the septic?—Not to be compared, absolutely not.

8217. (*Professor Ramsay.*) Is it true that your sewage stays 24 hours in the septic tank?—Very nearly, but not quite because we treated it from 1 to 1¼ times its volume so it was rather less than the 24 hours.

8218. I wondered if the septic conditions had only been half induced and that the septic fermentation went on on the fields?—I quite believe that they were properly induced for this reason, that whilst it works out at about 1¼ times its capacity the volume that we treated per day through it—we have had week end rests every week which I had not taken into consideration, and every week it had a week end's rest for putrefaction to go on when it was standing full.

8219. (*Colonel Harding.*) And that no doubt would actively develop the septic conditions?—It did very much so. I have only calculated actual working days and hours in taking this 1¼.

8220. And if you had the sewage to treat on grass land you would have preferred to take it direct from the detritus tank to the land rather than pass through this septic tank. That is what you want to tell us?—Yes, it is; but I should like to tell the Chairman one other observation. It appears to me, with great respect, that what you are trying to ascertain is whether if this septic effluent had got into actual contact with the soil, as the sewage did, under normal conditions, there would have been that nuisance from the septic effluent. Well, yes, there would, for this reason, that you will find in one of my replies on this question that the effluent which had passed through the top foot of soil and worked its way through the drain trenches down into the subdrains and discharged out again on to the land, thereby having had, of course, actual contact with the soil twice over, was extremely offensive when it came out of the drains. Now, if filtration through soil would have taken away that offensiveness, or in other words had it converted that anaerobic condition into an aerobic condition, it would have done it by passing through the land. I am afraid that filtering of septic effluent through soil, unless it is very extensive filtration indeed—well, in a very advanced stage of septic action—will not give very good septic results. That is the point I want to bring out.

8221. You prefer to confine the treatment to aerobic action?—Not absolutely confine it, Sir, but we get, of course, in our mile and a half of rising mains a certain amount of septic action.

8222. Which you cannot avoid?—No, Sir, having got a little septic action previously in the sewers, and when we put it through our detritus tank (and I am recommending a large capacity of detritus tanks), you get further septic action, but what we find is this, that it is better, instead of letting it get into an advanced anaerobic condition before you put it on to the land, to stop at a moderate anaerobic stage and then put it on to the land at that stage, than to allow it to get so advanced before you put it on. The same thing applies in the beds. It is a curious thing, but when we send the sewage straight into a first contact bed from the detritus tank without that septic tank we get even a better result from the first contact bed than we do when we send it through the septic tank as well as the detritus tank before we put it through that bed.

8223. (*Chairman.*) In your Processes 10 to 13, was it your object to endeavour to clarify sewage on the septic system before applying it to the grass land for final purification?—That was so. The sewage was first passed through the small detritus tank, then through the closed septic tank, and then treated by broad irrigation on the land, the area being changed every week.

8224. Then will you proceed to describe the second group of processes?—The second group of experiments deals with clarification in open and closed detritus tanks and first contact bacteria beds with final purification by broad irrigation. Process 5 was continued 71 days on this principle.

8225. (*Colonel Harding.*) It is necessary before you tell us anything about the results of this second group of experiments to tell us whether this is an experiment consisting first of a septic tank following a detritus tank, and then a contact bed, and then land?—Yes, that is it, Sir.

8226. Then it only lasted 71 days?—That particular one, yes.

8227. The septic tank was in septic condition when the experiment began?—That was Process 5, was it not? If you will pardon me this is not the septic, this is the open.

8228. Is it simple subsidence followed by contact bed and land, or is it septic followed by contact bed and land?—Oh! no, it is subsidence.

8229. (*Sir Michael Foster.*) Does not that mean an open septic tank?—Yes, it does; it is open, you know.

8230. Its being open or not does not seriously affect its being a septic tank, does it?—It is a septic tank.

8231. (*Colonel Harding.*) Had the septic conditions fully developed in this open septic tank when the experiments began?—Not when they first began.

8232. At first it was merely an ordinary subsidence?—Ordinary subsidence. We found in about a fortnight it became extremely offensive, and in three weeks to a month the anaerobic action was very marked, and it went on then, as you see, for the period mentioned—71 days.

8233. And in this experiment in the early part of it we had to deal with mere subsidence, and in the later part of it we have to deal with some septic development?—You do, Sir.

8234. (*Professor Ramsay.*) Would you describe the product of a septic tank as extremely offensive. Is that the normal action of a septic tank?—The ones I have seen I think are not what you might call offensive.

8234*. Does it depend on the kind of refuse that you have that you are turning into the tank, ordinary domestic sewage and ordinary trade effluent?—I do not think one could describe the ordinary liquid of towns from the septic tank as always extremely offensive.

(*Sir Michael Foster.*) Colonel Harding's experience is there is occasionally a bad smell.

8235. (*Colonel Harding.*) We have not found at Leeds any serious nuisance arise from septic tank effluents where septic conditions have fully developed?—We have found the reverse. It has been extremely offensive and more offensive when the septic conditions are ripe than it was even at the earlier stages.

8236. (*Sir Michael Foster.*) This particular experiment would hardly develop them because it was only carried on a little more than two months?—True.

(*Mr. Killick.*) There were three important experiments, 7, 14, and 17; if Mr. Mawbey will explain the difference between his three successes; failures we do not want to go into.

(*Sir Michael Foster.*) Is it not rather an interesting point the absence of bad smell from the subsidence tank?

(*Mr. Killick.*) That will come out from the comparison of the three with the final effluent.

(*Sir Michael Foster.*) It rather seems to indicate that there was something in the nature of the Leicester sewage which led to these offensive smells.

(*Colonel Harding.*) It might be.

8237. (*Professor Ramsay.*) The fellmongering?—Of course, there is not a great lot of that, the fellmongering sewage.

8238. (*Colonel Harding.*) That is, of course, very foul?—Yes, it is. The dye works are the predominant trade. I will tell you what we have got, Sir. Fellmongering, there is only about 1,000 gallons a day goes out; there is a great deal of wool washing you know that is offensive, and a large quantity from dye works, but that is not so offensive.

8239. If I may be allowed to point out I think the position is this, that your first experiment was an experiment with septic tank effluent on land, which you gave up for reasons that you fully explain?—That is it.

8240. Next you passed septic tank effluent in more or less septic condition, for a short period, only two months, over a contact bed, and then on land; is not that so?—Yes. Oh! we passed it for a long time. You see we passed it from the 1st of June.

8241. You said 71 days, did you not?—It is not septic action; you are on this process where it is an open subsidence tank—call it septic if you like, of course; but if you take the covered septic case it is different. You see this is where we began; this line is a septic tank, this black and green (*indicating on cartoon*).

8242. Have you an experiment where you put the

septic tank effluent upon a contact bed and then upon the land?—Yes.

8243. Will you tell us what the result was you obtained; did it minimise the objection as to offensiveness?—Yes.

8244. And did you get analytical results from the final filtrate after passing through the land which were satisfactory?—Yes, but what I want to bring out is this, that when we put this septic effluent through a bed and then on to the land it was no better than when we put it straight from the detritus tanks on to the land. In our experiments for clarification before putting the sewage on to the land we were no better off by using a septic tank in addition to the detritus tank before we put it through the first contact bed.

8245. That is in harmony with what you found in connection with land that the anaerobic treatment did not facilitate the subsequent aerobic?—It did not, Sir; it was not any improvement whatever; we had the most efficient clarification without it. It was always better when it came out of the second contact bed both in albuminoid ammonia and in oxygen absorbed. It was not only better than the complete septic effluent, but it was better than when the septic tank had been used as well as the first contact bed, so we found it no advantage whatever in our clarification scheme, having the septic tank in addition to the first contact bacteria bed.

8246. (*Chairman.*) Am I right in this: you found your best effluent came after it had passed through a closed detritus tank, and then gone on to the first contact bed?—Yes, my Lord, and then on to old pasture.

8247-9. And then on to the land?—Yes.

8250. (*Mr. Killick.*) I understand you to say that you have a long length of sewers, and there was septic action in the sewage as delivered at the detritus tank?—There is a little, but it is not so very much; it is not very long, Sir; we do not happen to have a very long outfall.

8251. (*Colonel Harding.*) In effect it is putting fresh sewage minus grit on a contact bed, and then finishing up on land?—Yes, it was slightly septic, but nothing to speak of, nothing to say much about.

8252. Then you proceeded, did you not, to try the sewage passing through the detritus tank, only on to a contact bed, and then on to the land?—Yes, with the most successful results of any.

8253. Very well, would you give us them?—We started doing that here; we started on the 1st September, and put the sewage from that tank through a bed, and then through land, and we carried it through the whole of the experiments, and the result of the whole thing is this, that taking the albuminoid ammonia, the average of all those months, in fact right clean through the experiments, the average was that in albuminoid ammonia we got 86 per cent. of purification from the crude in this No. 7 process, and we got 91 per cent. of oxygen absorbed; in fact, it was at once, in a word, the most successful of all the clarifying systems to send it through a closed detritus tank, and then on to a contact bed, and then on to the land. Now what happened was, we never had the slightest nuisance nor any fouling of the grass excepting for a distance of about 12 yards from the top feeding grip when we treated sewage which had only passed through the detritus tank and the first contact bed.

8254. We may take it there would be septic action on the way to the works?—Yes, a little.

8255. But apart from that it is as I say?—Yes.

8256. And the results were satisfactory?—Yes.

8257. (*Chairman.*) Have you tried putting it through the second contact bed as well as the first?—Yes.

8258. Now does that improve it?—Yes, that is Process No. 14. I will show you the difference. When you have finished it on old pasture you have got an average of 86 per cent. of purification, and when instead of putting it on to old pasture you put it through a second contact bed you got 83 per cent., so that the double contact bed treatment is not quite so good as the single contact and the land. The same thing bears out in oxygen absorbed whereas single contact bed and land gives you 91 per cent. of improvement the double contact gave you 90 per cent. Then might I go on to say that we also went to a third contact bed.

8259. You went on to a third contact bed?—We also carried on experiments with a third contact bed. *Mr. E. G. Mawbey.*

8260. (*Mr. Power.*) Your "single contact and land" meant three times applied to land after passing the bacteria bed?—No. 7 Mar. 1901.

8261. Not to three separate plots?—That is in the normal treatment of the farm what we do now, but with only one exception, we never put it over more than one plot of land throughout these experiments. That is a very important answer, if you will allow me to say so.

8262. (*Sir Michael Foster.*) You mean to say you have got with your contact beds with one plot of land as much improvement as you get with the land with three?—With three. Yes, No. 17 process is the three contacts, and the purification was 86·74 per cent.; that is the average over all the analyses taken, whereas the first contact and the land was 86·76. You see there is no difference. Then oxygen absorbed, from crude sewage; there is a purification in the one contact and the land of 91·08, and in the three contacts we get 91·32, so shortly it is this that the detritus tank, the first contact, and the application to one plot of old pasture is equal to the detritus tank and three contacts and superior to the detritus tank and two contacts.

8263. (*Major-General Carey.*) In the last experiments of double contact beds were you putting the same volume of sewage in proportion per acre as you were in the original broad irrigation treatment?—On to the land?

8264. On to the land; was it the same proportion?—No, greatly more, sir. When we put the effluent from the contact beds on to the land we put it on at the rate of 1,000,000 gallons per 24 acres in use at one time, whereas with broad irrigation without any clarification it always took about 50 to 54 acres of land in use at one time per 1,000,000 gallons. In addition to that you must of course know that when I say "in use at one time," you have got to have for the treatment four to five times those areas, so that you can have plenty of land in rest. In other words, that taking the 24 acres per 1,000,000 gallons in use at one time with a clarified effluent from the first contact bed you ought to have at least four times that, because of rest and cropping. The same thing applies to the broad irrigation without clarification, you ought to have four or five times the 50 acres per 1,000,000 gallons. But I might say one word in reply to that. What we find is this, that with the detritus tank and the first contact bed for clarification we can treat from two to three times, I should say quite three times as much sewage on the land as you can without this system of clarification. That is the result of our experiments.

8265. (*Chairman.*) You will no doubt hand in all your analyses?—Yes, I will.

8266. I should like just to know what you have found about the question of sludge?—Taking a detritus tank from September 1st to November 10th, we emptied this tank four times, or an average of about once in two to two and a-half weeks, and in that detritus tank we produced an average of 8·29 tons of sludge per 1,000,000 gallons. We reduced everything to 90 per cent. of water, so that makes it to the standard 9·53 tons per 1,000,000 gallons in the detritus tank.

8267. Was the detritus tank open or closed at that time?—It was open then.

8268. (*Colonel Harding.*) This eight tons per 1,000,000 gallons is mere mineral matter?—Well, I think there is some organic and light stuff in it as well.

8269. The amount of it is so small that it would only consist of the grosser solids?—It is the grosser solids.

8270. Eight tons per 1,000,000 gallons is very little. One may say the bulk of the suspended matter went forward on to the beds, went on to the land?—Yes, a very great deal of it did, yes.

8271. (*Chairman.*) Then was the tank closed after that time?—It was.

8272. And when was it next emptied?—Then we worked it for 90 days without emptying, and the sludge produced in that time was 6·21 tons per 1,000,000 gallons, 90 per cent. of water.

8273. Then that was less than when it was open?—Yes.

8274. And you left it a much longer period then without cleaning it?—We did.

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8275. Then when did you next clear out the sludge?—After a further 151 working days, and the yield of the sludge during that period was 2·32 tons per 1,000,000 gallons at 90 per cent. of water. Then we went on, and worked it for 22 days, and it produced 6·70 tons, at 90 per cent. of water.

8276. Then would not your experience be that the longer you left it without emptying the less sludge it would produce?—That would be so.

8277. (*Colonel Harding.*) What would that be due to?—This is the reason, sir. I think the small quantity of sludge produced in this tank during the two periods, that is the first two long periods, was largely accounted for by the very long periods that this closed tank was used without emptying, because we found that when this sludge in the tank had reached a considerable height, the whole contents of the tank were thick, and a good deal of the solid matter floated out in large lumps.

8278. In other words, the tank emptied itself?—Yes, it emptied itself, the whole mass bein gin a violent state of fermentation. Although not as much sludge was found in the detritus tanks in the long periods you found it in the septic tank, it works itself off, and you will see that taking the two together there was about the same quantity of sludge produced in the two as there was in the detritus tank when often emptied.

8279. (*Chairman.*) Will you just give us your experience of the sludge in your open subsidence tank?—The open subsidence tank, the long one, was emptied after 10 days' work, and the yield at 90 per cent. of water was 4·45 tons per 1,000,000 gallons. It was then used for 72 working days, when it was found that the sludge equalled about two tons at 90 per cent. As with the detritus tank, the longer the working period the smaller is the quantity.

8280. (*Colonel Harding.*) For the same reason?—For the same reason, but you find it in the two together, you get about the same quantity. We found that after working the closed septic tank for 4½ months without emptying, from June to October, the yield in this period was seven tons per 1,000,000 gallons, at 90 per cent. of water, and then the amount of sludge produced in the closed detritus tank and the septic tank, taken together, amounted to 10·84 tons per 1,000,000 gallons, at 90 per cent. water, so that you seem to produce this 10 or 11 tons of sludge per 1,000,000 gallons at 90 per cent. of water, whether you get it by cleaning out the detritus tank often or whether you let them work on and catch it in the two together.

8281. (*Chairman.*) Could you give us any information about the water capacity of your bacterial beds?—I have prepared a table, which I will hand in, from which you will see that the water capacity, which was measured on the 24th of September, 1898, after about a month's working, was 61,865 gallons, which equals 49·54 per cent. of the total clinker and water capacity, but taking it after they had got into use there was 50 per cent. of water capacity, and when we worked it for nearly four months the water capacity came down to 36 per cent., and then when we worked it a further seven months, and after 3½ days' rest, it was 34·22 per cent. of the total capacity, and then a month later, after the beds had finished working altogether, we found that it was 29 per cent.

8282. Did you find that the efficiency of the beds increased with time or otherwise?—Well, that is a strange thing, my lord, we did not. You will find if you examine those tables that the efficiency of those beds, both for suspended matter and chemical, was no better in the last period of the time than in the first period; they were just about equal. There was no improvement, and in fact I should be rather inclined to think that unless they had very ample rest they would be more likely to slightly deteriorate than improve. They did not improve.

8283. (*Sir Michael Foster.*) You said something about a case of anthrax upon your farm, did you not?—Yes, I did.

8284. Can you tell one the history of that?—I could get that for you; I could not give you the history.

8285. Was it one case of anthrax or more than one?—I think we only had one case; it was reported to the Committee; I do not think we had more than one case.

8286. Could you trace the contagion in any way?—I could get that out for you, sir; I did not investigate it myself.

8287. Was it investigated at all?—Yes, it was; I know we investigated it; we had a veterinary surgeon who investigated it for us.

8288. You do not know what conclusion he arrived at?—It was some years ago; I am not acquainted with that.

8289. Some years ago?—Some years ago; nothing lately.

8290. Nothing lately?—No, sir.

8291. Have there been any suspected hides in the tanners' factory?—There was some suspicion of that sort, but I should only be trying to make the case up or guess if I attempted to give you the information. I will get it up for you.

8292. It would be rather desirable to get that knowledge whether any of the anthrax on the farm could have been traced to the sewage. You have curriers' refuse in the sewage, and I should like to know whether possibly infected hides used by the currier gave rise to anthrax in the sewage, and so to anthrax on the farm?—I did not quite finish that answer about the capacity of the beds. I should like to put it in a simple statement to this effect, that after we had got a start with our beds we had 50 per cent. of water capacity and at the end, after a little rest, after all the experiments were done we had 33 per cent. capacity, or one-third. The water capacity was reduced from a half, you see, to a third, as the result of the whole thing.

8293. (*Professor Ramsay.*) You settle your sewage, do you not, for about two hours before it passes on to the land?—I cannot say we settle it as long as that; do you mean in the ordinary working?

8294. In the ordinary working you give it a certain amount of settlement?—It would sometimes amount to nearly two hours in the present ordinary working.

8295. Is there any nuisance arises from those tanks?—Yes, when they are worked too long.

8296. That is to say when they are not cleaned sufficiently often?—When you say "offensive smell" it is right in the centre of 1,700 acres of land, so there is no nuisance, but there is offensive smell though.

8297. In answer to questions which have been addressed to you, you speak of the reduction of solids in the closed detritus and septic tanks; the solids are reduced by 83 per cent., and in the open subsidence tank by 84 per cent.?—Yes, sir.

8298. Do you not consider those very large figures. For example, in Manchester they make a reduction o 58 per cent. by subsidence, of the total solids?—Yes.

8299. Do you think your solids are more easily settled than ordinary solids in sewage?—I think the first percentage is easier settled, because it consists of road detritus to some extent. Yes, we have always got a very free subsidence in the first tanks. I should like to say that there is a preliminary subsidence before it gets to the farm in our outfall sewer. We get some deposit there as well, which we clean out periodically in the trunk end sewer.

8300. (*Mr. Killick.*) Are your roads paved or macadamised?—A good many of them are macadamised.

8300*. That might explain the difference?—

8301. (*Professor Ramsay.*) It might very probably?—Yes, sir.

8301*. Then, in answer to another question as to the demolition of the light sludge in the second tank, do you know whether your Leicester sewage is particularly nitrogenous; is there much fibre in it?—Yes, there is.

8302. More than usual do you mean?—Yes, there is; it comes from the shoddy, the wool scourers; there is a good deal of fibre.

8303. Particularly nitrogenous?—I should think it is no doubt.

8304. And then in your answer to other questions you speak of the nitrifying power of one plot of old pasture after detritus tank and first contact bed being somewhat greater than that of the second contact bed. What time of year; would such an answer apply all the year over, or does it apply to summer or to winter?—It was generally so, sir. Process 14 Table will give you that. It extended through a very long period, and it was generally superior. It was over a period from December to July.

8305. That is a pretty fair average of the year?—Yes, sir, it is.

8306. Six months of the year, including both winter and summer?—Yes, sir.

8307. (*Dr. Russell.*) How long do you calculate that any portion of the sewage sent from your septic tank was detained in it?—Detained in the septic tank, sir?

8308. Yes?—It would never be detained for less than about 18 or 20 hours—from that to 24 hours.

8309. Somewhat less than the 24 hours, as a rule?—It was as 1¼ is to 1.

8310. Of course this case differs from the usual method, that is to say you got your septic tank before you got your quantity of sewage returned that was to be treated in it?—Oh, no, what we tried to do was this, sir; we tried to send a proper quantity through the septic tank; that is to say to work it roughly at a day's capacity, so that it was in the tank 24 hours, but it did go up to as much as 1¼ times the capacity, so that it would reduce it, although a great deal of it was 24 hours it did reach up to 18 and 20 hours, that we got through as fast as that at times, but against that there were all those week end rests, where the anaerobic action was going on fermenting the tank full of sewage.

8311. You have just told us of an instance in which the deposit of sludge got to such an extent that it was running away in masses from your septic tank?—Yes, that was from the first detritus tanks, where it came out in flakes like that.

8312. And did it go into a septic tank from the detritus tank?—Yes, straight in, we found it when we measured the capacity.

8313. What I want to be at is do you think it is a perfectly fair conclusion as to the efficacy of the septic tank properly worked as it is installed at Exeter, for instance, to conclude from that what is the relation to broad irrigation?—Oh, I think so, sir. It is true that in later schemes I believe the tanks are worked rather slower than the total day flow, and we worked it a little fast sometimes, but broadly I think it is about fair, sir. We were very careful about trapping the inlets and outlets, and I had Mr. Martin to see the tanks after the experiments were over. He asked to come, and I asked him if he could find any fault with them. I told him all I had done, and exactly how I had done. He did not find any fault whatever at the time, and I showed him the sludge that we had produced. He did afterwards say that in their newer septic tanks they had improvements which we had not got—such as a slotted pipe, which I think is an advantage, so that there is no doubt that the later installations of septic tanks are better than the septic tank that we use.

8314. There is no doubt whatever from your evidence that you succeed in producing a very filthy effluent from this septic tank. The doubt in my mind is whether this was a septic tank worked as it ought to be worked?—Well, as I say, Mr. Martin did not find any fault with it, and the inlets and outlets were carefully trapped, and it was made as absolutely air tight as it was possible to make it. It was a tank constructed with brickwork and cement concrete; it was covered over with a layer of asphalte on purpose to make it air tight.

8315. (*Colonel Harding.*) It could not possibly be air tight?—As air tight as possible.

8316. It could not by any possibility work if it were. The gases must get out; they cannot remain confined within it?—Well, of course, they are absorbed through the walls the same as they are in all septic tanks. It was as air tight as we could make it. The gases go out; they must do in the very best constructed septic tanks, but we made it as air tight as practicable.

8317. (*Dr. Russell.*) Was there ever any scum on the top?—Oh, yes, sir, there was.

8318. Did it vary in thickness from time to time?—It was not a very thick scum; it was not so thick a scum as we get when we send the sewage into a big tank without a preliminary detritus tank.

8319. Of course, it was long and shallow as compared with the Exeter tank, it was 130 feet long?—30ft. wide.

8320. And 6 feet deep at the inlet, diminishing to outlet. I am not here to say, and do not wish to say that that I believe I think one of the Exeter representatives told me that their tank was too shallow for the best septic principles.

8321-2. (*Colonel Harding.*) We noticed that you clearly formed the opinion that the septic action is not helpful to you either for filtration on land or filtration on contact beds?—That is for our case.

8323. That is the conclusion you have come to?—For our case, but simply for that. Let me make it very plain. I am not here to say and do not wish to say that the septic system may not be suitable in other towns under other conditions.

8324. You are speaking to us of Leicester?—Yes, and where land is not available; it might be a most admirable system. I will not say a word about that; I am only dealing with the conditions at Leicester.

8325. The point in connection with the septic tank, raised by Dr. Russell, is that the speed was the right speed of flow to bring about septic action, but the experiment does not seem to have been continued long enough to bring about the fullest septic action. It has been found at Manchester, Leeds and other places that it takes three or four months to fully develop the fullest septic action. It would have been more satisfactory to carry on this experiment for a year. We should have been interested to discover if possible why the septic effluent at Leicester should be so exceedingly foul, because our experience of it at other places, where there are trade effluents mixed with the domestic sewage, has not been the same. There is a certain foulness in the effluent, but it has not been striking. We have seen it at Accrington, Manchester, Leeds and elsewhere. Can you suggest to us any reason why at Leicester it should be specially foul?—I am afraid I cannot, only that what I do say is that when it runs straight from the septic tank into the body of the bed, straight into it, you will not appreciate its offensiveness at all; at least not very much, but where you spread it over acres of land you appreciate it then most fully, so that that may be some explanation.

8326. Your answer is an interesting one. You suggest that using septic tank effluent upon a contact bed you would be less likely to find a nuisance arise than spreading it over a large area of land?—Oh, yes, certainly, most emphatically, so that if you can get it straight from the septic tank on to a contact bed I do not think that there is very much fear of a nuisance.

8327. Then in regard to its utility in preceding a contact bed we need not take into account the question of nuisance; you do not foresee that used with the contact bed the nuisance would be serious?—I do not think it would.

8328. In using the septic tank you would expect, would you not, some of the suspended matter deposited in the tank?—Oh, of course.

8329. In fact, in one of your answers I think you tell us that the passage through the detritus tank had given you in connection with the suspended matter a purification of about one-half?—Yes.

8330. And that after passing through this septic tank that proportion had been increased to 83 per cent.?—Yes.

8331. You have stated in answer to a question: "This table shows that the percentage of purification on the crude sewage in suspended matters was 55·28 after passing through the closed detritus tank, and 83·01 after passing through the septic tank"?—Yes, that is right.

8332. And therefore the passage through the septic tank even from the detritus tank would give you the difference between 55 and 83?—Certainly.

8333. If you used the septic tank that amount of suspended matter was kept back from going on the contact bed?—It was.

8334. If you dispense with the septic tank and work with the contact bed that amount of suspended matter goes on to the contact bed in addition to what went on to it before?—Certainly.

8335. Now, the whole matter rests here in regard to this experiment, whether any evil results are likely to follow from dealing with this additional suspended matter on the contact bed; in other words, has the capacity been reduced? You have told us the analytical results were not made any worse, but the point arises whether you can deal permanently on a contact bed with half the suspended matters on the sewage; is not that the point?—Exactly.

8336. You have given to us in one of your later answers the reduction of the capacity as being from one half to one third, and that was after working the whole period of your experiments, but I do not want that; I want the middle period?—Yes.

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8337. Would you mind telling us how long the contact beds worked together in various ways with or without septic tank?—13½ months.

8338. Then am I right in gathering from your figures that after working 13½ months the capacity of those tanks had been reduced only from one half to one third of the total capacity of the tanks?—It went down to 29 per cent. immediately we had finished, but after resting a few days it recovered itself up to one third, yes.

8339. Up to one third?—Yes, that is it.

8340. Do you not find that these recoveries are soon lost again?—Oh! yes, they go down again, but they keep recovering.

8341. Then the conclusion you put before us is that after working 13½ months the tanks which in the first instance had a water capacity of 50 per cent. at the end of the period had a water capacity of 30 per cent?—Well, yes, rather more than 30 per cent.; between 30 and 40.

8342. Then there was a reduction in water capacity of only 40 per cent. in the period, the difference being 50 and 30?—It was 33 per cent.; you see the difference.

8343. The difference between 50 per cent. at the beginning and 30 per cent. at the end is 40 per cent., is it not?—Yes.

8344. That is against our experience in other directions, and I must ask you how are your measurements made? How did you measure the capacity of your tanks?—We measured the capacity in the first place by filling the detritus tank and emptying it; we carried out several experiments with our weir which we have at the bringing on channel; we carried out a number of experiments to find out what was the proper formula for gauging the water over this weir, and having found a slight modification of the formula that would answer we gauged it every quarter of an hour. I mean every five minutes a man stood there and watched it. We have got figured gauges there over the weir.

8345. Would that be really a reliable test?—Oh, yes, it is reliable, because the formula was checked by absolute measurement in tanks.

8346. The tank being the detritus tank?—Yes.

8347. Which had been emptied of sludge?—Oh, yes.

8348. And you used the detritus tank as a measure; you put so many times the volume of the detritus tank into the bed and measured in that way?—That we did at first, but it was done by the weir afterwards.

8349. At first you measured more or less accurately, and later on by the weir only?—The whole of them were based on the weir calculation, right the way through; all we did was to check the weir by the capacity.

8350. You are proposing by your experiments to apply at Leicester a sewage treatment which is to consist first of settlement of about half the suspended solids in a detritus tank, to be followed by a contact bed which is expected to deal with a considerable part of the other half of the suspended matters in the sewage and finally by land?—That is so.

8351. Well, it is obviously of great importance for you to ascertain, is it not, whether your contact beds would be able to maintain their capacity dealing with half the suspended matters in the sewage?—Yes, it is; well, what we think we found out is this——

8352. It is a point I would suggest well worthy of your careful consideration to get the most accurate measurements to find out, because as far as we have been able to see the reduction of capacity goes on at a greater rate in other places, with half the amount of suspended matters in the sewage?—In other places. I will tell you what I am going to do in this scheme; I am having the detritus tank capacity very liberal. They are to be open tanks, and the capacity that we are going to have is 1,400,000, or nearly 1½ millions out of 8 million gallons of dry weather flow, so I quite appreciate what you say, Sir, that it is very necessary that we shall have very ample preliminary detritus tanks. And we shall get some septic action in those open detritus tanks.

8353. Not necessarily; if you empty them too frequently?—Not necessarily if we empty them too frequently, but we are just in this happy position that we are on the top of a mountain as it were in the middle of 1,700 acres of land, and we dare go on longer there with these tanks before emptying them than you could if you had got houses round. Now, three of those beds have been confined absolutely to this detritus tank effluent without the septic, so we find from working 13½ months into three of those beds that the capacity is only reduced from 50 per cent. of total to 33 per cent., so we think that with this very ample detritus tank capacity we may hope to succeed.

8354. Are you continuing those experiments?—No.

8355. It seems rather desirable that you should, to give us experience and yourselves?—There is another advantage we have. We shall have, you see, the 1,700 acres of land, or 1,355 the figure is for actual sewaging.

8356. Could you not use these contact beds in the way you are now using them, finding out really how long they go before the capacity is too far reduced?—You mean go on with them now.

8357. Yes?—Keep going on with the experiments; start them again.

8358. Would it not be very advisable to do so in your own interest?—I should think so. Of course, we have had 13½ months at them, you know, and we think that a good test.

8359. We should be much interested to see whether it is possible to maintain capacity at that one-third working with half the suspended matters in crude sewage; we should be interested to see if that is possible, but if you stop the experiments we cannot see it.

8360. (*Chairman.*) I want in the name of the Committee to thank you for the facilities you have afforded us?—I am very pleased, my Lord.

SEWAGE EXPERIMENTS AT BEAUMONT LEYS FARM.

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TABLE showing AVERAGE, BEST and WORST Analyses, of the Final Effluents of each Process.

Number of Process.	Suspended Matters.			Albuminoid Ammonia.			Oxygen Absorbed.		
	Analyses.			Analyses.			Analyses.		
	Average.	Best.	Worst.	Average.	Best.	Worst.	Average.	Best.	Worst.
2*	0·56	0·56	0·56	0·2464	0·2464	0·2464	1·4715	1·4715	1·4715
3	0·187	0·140	0·280	0·2081	0·1904	0·2170	0·7162	0·6041	0·8552
4	0·35	0·14	0·56	0·2086	0·1932	0·2240	0·7320	0·6717	0·7923
5	0·644	0·14	2·38	0·2189	0·1764	0·2940	0·8781	0·6041	1·2899
6	0·38	0·14	0·70	0·1946	0·1470	0·2240	0·6711	0·4740	0·7923
7	0·385	0·00	1·26	0·1565	0·1134	0·2338	0·6634	0·2065	1·1214
8	No final effluents analysed from the Rye Grass.								
9	0·31	0·14	0·42	0·1463	0·1120	0·1722	0·7061	0·6524	0·7512
10	No final effluents analysed from the Rye Grass.								
11	0·14	0·14	0·14	0·1832	0·1610	0·2394	1·1679	1·0222	1·3183
12*	0·14	0·14	0·14	0·1316	0·1316	0·1316	1·2369	1·2369	1·2369
13	No final effluents analysed from the Rye Grass.								
14	1·60	0·42	3·08	0·2106	0·1134	0·3444	0·7474	0·5840	1·2983
15	1·64	0·84	2·52	0·2027	0·1433	0·2576	0·7412	0·6074	0·8468
16	1·19	0·70	1·68	0·1442	0·1176	0·1708	0·7459	0·7063	0·7855
17	·49	0·14	0·84	0·1809	0·1694	0·1960	0·6787	0·5684	0·8638

* Only one analysis made of this Process.

March 1901.

E. GEORGE MAWBEY, *Borough Engineer*, Leicester.

Mr. E. G. Mawdsley. 7 Mar. 1901.

SEWAGE EXPERIMENTS AT BEAUMONT LEYS FARM.

PROCESS No. 8, viz :—1. Crude Sewage. 2. Closed Detritus Tank. 3. Septic Tank. 4. Clarifying Bacteria Beds. 5. Rye Grass. Quantities stated in grains per gallon.

Duration of Process.	No. of Times Beds Filled per Day.	Date Analysis Taken.	Suspended Matters.					Albuminoid Ammonia.					Oxygen Absorbed at 80° F. in 4 hours.					Nitrogen as Nitrates.					Matters in Solution.				
			Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Beds.	Rye Grass.	Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Beds.	Rye Grass.	Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Beds.	Rye Grass.	Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Beds.	Rye Grass.	Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Beds.	Rye Grass.
1899.		1899.																									
1899.		1899.																									
24 July to 15 Sept.	3	26 July	60·99	No Analysis.	11·34	3·92	No Analysis.	1·2110	No Analysis.	0·4858	0·3752	No Analysis.	7·5684	No Analysis.	3·1500	1·5723	No Analysis.	0·03	No Analysis.	0·03	0·06	No Analysis.	74·2	No Analysis.	60·9	60·9	No Analysis.
		2 Aug.	38·50	„	10·22	4·20	„	0·8190	„	0·4900	0·3724	„	6·5815	„	2·9930	1·2270	„	0·03	„	0·03	0·03	„	65·8	„	65·1	68·6	„
		16 „	22·40	„	9·10	1·82	„	0·8624	„	0·4116	0·2473	„	5·8719	„	3·1977	1·1229	„	0·03	„	0·03	0·06	„	74·9	„	60·9	60·2	„
		23 „	10·50	„	11·48	2·80	„	0·9961	„	0·6388	0·4310	„	7·9808	„	5·8721	2·2986	„	0·03	„	0·03	0·06	„	89·6	„	75·6	78·4	„
		30 „	51·80	„	10·08	1·12	„	1·1585	„	0·6888	0·3780	„	8·0732	„	4·8025	1·5268	„	0·01	„	0·03	0·06	„	71·4	„	68·6	67·2	„
		6 Sept.	31·50	„	No Analysis	No Analysis	„	0·8365	„	0·4802	0·2268	„	6·0666	„	4·6078	1·5218	„	0·03	„	0·01	0·03	„	60·2	„	63·7	61·6	„
		13 Sept.	30·80	„	7·00	3·92	„	0·9310	„	0·4354	0·3570	„	8·3372	„	5·2948	2·7455	„	Nil	„	0·03	0·01	„	71·4	„	65·8	37·2	„
		Totals - -	246·40	„	59·22	17·73	„	6·8745	„	3·6306	2·3877	„	50·4800	„	29·9179	12·0149	„	0·16	„	0·24	0·31	„	507·5	„	460·6	464·1	„
		Averages - -	35·20	„	9·87	2·96	„	0·9735	„	0·5187	0·3411	„	7·2114	„	4·2740	1·7164	„	0·023	„	0·034	0·044	„	72·1	„	65·8	66·3	„
Percentages of purification on Crude Sewage - -			-	-	71·96	91·59	-	-	-	46·72	64·96	-	-	-	40·73	76·20	-	-	-	-	-	-	-	-	-	-	-

SEWAGE EXPERIMENTS AT BEAUMONT LEYS FARM.

PROCESS No. 9, viz 1. Crude Sewage. 2. Closed Detritus Tank. 3. Clarifying Bacteria Beds. 4. Old Pasture. Quantities stated in grains per gallon.

Duration of Process.	No. of Times Beds Filled Per Day.	Date Analysis Taken.	SUSPENDED MATTERS.				ALBUMINOID AMMONIA.				OXYGEN ABSORBED at 80° F. in four hours.				NITROGEN AS NITRATES.				MATTERS IN SOLUTION.			
			Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Beds.	Old Pasture.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Beds.	Old Pasture.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Beds.	Old Pasture.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Beds.	Old Pasture.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Beds.	Old Pasture.
1899.																						
19 September to 13 October.	4	20 September -	20·65	16·10	2·10	0·42	0·9730	0·7630	0·2730	0·1526	6·4358	6·0130	1·8970	0·7281	Nil	0·03	Nil.	0·76	70·0	68·6	63·0	71·4
		27 „ -	29·75	14·00	5·88	0·28	0·8645	0·8470	0·3640	0·1722	6·8955	5·5720	2·0496	0·6928	Nil	0·06	0·03	0·22	79·8	70·0	70·0	68·6
		4 October - -	34·65	16·10	5·46	0·42	1·0465	0·7560	0·3150	0·1120	7·4984	4·6526	1·8802	0·6524	0·03	0·03	0·01	0·32	67·2	60·2	60·2	70·0
		11 „ - -	70·00	18·90	4·48	0·14	2·5725	1·7920	0·4900	0·1484	10·4342	7·0700	2·4584	0·7512	0·03	0·03	0·03	0·03	74·2	72·8	74·2	81·2
		Totals - -	155·05	65·10	17·92	1·26	5·4565	4·1580	1·4420	0·5852	31·2639	23·3076	8·2852	2·8245	0·06	0·15	0·07	1·33	291·2	271·6	267·4	291·2
		Averages -	38·76	16·27	4·48	0·31	1·3641	1·0395	0·3605	0·1463	7·8159	5·8269	2·0713	0·7061	0·015	0·037	0·017	0·33	72·8	67·9	66·85	72·8
Percentages of purification on Crude Sewage -			—	58·02	88·44	99·20	—	23·79	73·57	89·27	—	25·44	73·49	90·96	—	—	—	—	—	—	—	—

SEWAGE EXPERIMENTS AT BEAUMONT LEYS FARM.

PROCESS No. 14, viz.: 1.—Crude Sewage. 2.—Closed Detritus Tank. 3.—Clarifying Bacteria Bed, No 1. 4.—Fine Bacteria Bed. Quantities stated in grains per gallon.

Duration of Process.	No. of Times Beds Filled per Day.	Date Analysis Taken.	Suspended Matters.				Albuminoid Ammonia.				Oxygen Absorbed At 80° F. in four hours.				Nitrogen as Nitrates.				Matters in Solution.			
			Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Bed, No. 1.	Fine Bac. Bed, 2nd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Bed, No. 1.	Fine Bac. Bed, 2nd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Bed, No. 1.	Fine Bac. Bed, 2nd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bac. Bed, No. 1.	Fine Bac. Bed, 2nd Contact.	Crude Sewage	Closed Detritus Tank.	Clarifying Bac. Bed, No. 1.	Fine Bac. Bed, 2nd Contact.
		1893.																				
28 November 1893 to 19 July 1899.	3	6 December	169·05	31·50	4·34	1·12	3·0905	0·9870	0·3472	0·2758	11·8238	7·8104	3·1536	0·8743	0·06	0·06	0·09	0·09	70·0	72·8	70·0	72·8
		14 „	38·50	20·65	6·72	0·56	1·0920	1·0395	0·5068	0·2800	9·9103	7·7861	4·9418	1·2983	0·09	0·09	0·09	0·08	72·8	73·5	73·5	71·4
		21 „	52·50	14·70	4·20	2·10	2·2425	0·9590	0·3234	0·2842	8·4642	6·6346	1·7432	0·8904	0·06	0·08	0·09	0·06	72·8	72·8	72·8	75·6
		28 „	40·60	17·50	3·50	0·98	1·6940	1·2880	0·4088	0·3444	7·7589	5·1230	1·2255	0·8101	0·12	0·12	0·54	0·64	75·6	70·7	71·4	75·6
		1899.																				
		2 January	60·55	15·40	6·16	3·08	1·0395	0·7350	0·3206	0·2716	4·9548	3·2109	1·4095	0·6498	0·41	0·28	0·08	0·38	70·0	60·2	67·2	74·2
		11 „	78·40	21·35	3·50	0·56	1·2565	0·8820	0·3556	0·1736	9·8000	8·5837	3·4868	0·6736	0·06	0·09	0·11	0·41	74·2	74·2	64·4	65·8
		18 „	46·90	19·60	4·62	1·40	1·5680	1·0185	0·3262	0·1456	8·2791	6·5928	1·9233	0·6305	0·06	0·06	0·06	0·51	74·2	71·4	74·9	72·8
		26 „	27·65	17·15	1·68	1·54	0·9765	0·9345	0·2940	0·1862	6·1966	5·0950	1·8095	0·5966	0·06	0·06	0·04	0·38	75·6	71·4	72·8	77·0
		2 February	58·80	18·90	4·20	2·94	1·3720	1·0500	0·3458	0·2436	8·6070	6·4010	1·5775	0·9840	0·01	0·09	0·01	0·32	82·6	77·0	77·0	71·4
		9 „	32·20	23·80	5·32	1·40	0·8540	0·7000	0·2604	0·1372	6·2633	5·2082	1·5121	0·6585	Nil	0·01	0·06	0·41	68·6	63·0	67·2	70·0
		16 „	27·65	17·50	3·50	1·54	0·9100	0·8190	0·3150	0·2114	6·0912	5·0848	1·3962	0·5840	0·03	0·03	0·01	0·48	77·0	72·8	70·7	78·4
		22 „	37·10	23·80	7·98	1·82	1·2355	1·1655	0·5401	0·2548	6·0068	5·1493	3·5611	0·6125	0·03	0·03	0·03	0·48	75·6	75·6	76·3	72·8
		3 March	39·20	21·70	5·74	1·96	1·1690	0·9240	0·4494	0·2212	7·0770	5·5305	1·5386	0·5894	0·03	0·03	0·03	0·40	70·0	70·0	67·2	68·6
		15 „	39·90	14·70	6·58	1·26	1·2285	0·8400	0·4536	0·2254	7·9896	5·3780	1·6606	0·6613	0·03	0·03	0·03	0·22	74·2	71·4	72·1	77·0
		24 „	27·30	17·85	5·88	0·84	0·9485	0·8820	0·3976	0·1554	5·7584	5·7848	2·7076	0·6076	0·03	0·03	0·06	0·35	68·6	72·8	72·8	71·4
		29 „	29·40	19·25	5·88	1·82	0·9100	0·8505	0·4550	0·2380	7·8558	4·0979	2·8226	0·9240	0·03	0·03	0·03	0·22	72·8	74·2	72·8	74·2
		12 April	25·90	16·80	2·80	0·42	0·8995	0·6230	0·2618	0·1372	7·9135	6·4948	2·5214	0·6595	0·03	0·03	0·06	0·48	71·4	67·2	68·6	70·0
		19 „	33·25	15·40	3·22	2·10	1·1025	0·6930	0·4060	0·1848	8·2236	6·4890	2·9969	0·9147	0·03	0·01	Nil	0·38	75·6	70·0	73·5	72·8
		26 „	60·55	19·25	5·04	1·68	1·2425	0·7560	0·3444	0·1470	9·6852	6·7474	2·8779	0·6334	Nil	Nil	0·01	0·54	77·7	75·6	70·0	67·2
		3 May	30·10	20·65	6·44	2·10	1·1725	1·0395	0·3990	0·2590	7·8085	7·5100	3·1689	0·8736	0·01	0·01	0·01	0·16	84·0	84·0	77·0	74·2
		10 „	33·50	21·70	7·42	4·06	1·1970	0·8645	0·3850	0·1778	6·6557	6·2563	2·7403	0·6563	0·01	0·03	0·06	0·40	85·4	82·6	79·8	77·0
		17 „	30·10	22·40	4·20	1·96	1·1130	0·7700	0·3122	0·1134	4·3355	4·1963	2·0186	0·5961	0·01	0·01	0·03	0·35	67·2	65·8	63·0	63·0
		7 June	23·80	14·70	4·20	1·96	0·6636	0·6566	0·3962	0·2324	5·9885	4·7118	1·9549	0·6475	Nil	Nil	Nil	0·44	65·3	67·2	67·9	61·3
		14 „	59·50	28·70	8·12	1·68	0·9415	1·0535	0·4102	0·1890	6·6012	6·8867	2·7387	0·8013	0·03	0·03	0·03	0·22	79·3	84·0	73·5	70·7
		21 „	33·20	18·20	4·76	1·40	0·9415	0·7630	0·2940	0·1904	6·6012	5·0360	2·6152	0·8895	0·01	0·01	0·03	0·12	68·6	67·2	63·0	60·2
		28 „	53·90	20·75	4·90	1·82	1·4595	0·9415	0·3206	0·2730	9·2950	7·2065	1·8578	0·9408	0·01	0·01	0·03	0·12	69·3	60·9	57·4	56·0
		5 July	29·75	22·05	5·78	1·12	1·0570	0·9450	0·2926	0·1736	5·7974	4·6351	1·9024	0·6729	Nil	0·01	0·03	0·25	64·4	63·7	63·0	63·0
		12 „	73·45	26·25	5·74	0·42	1·7585	0·8355	0·3220	0·1904	11·1384	5·2388	2·0832	0·6705	Nil	0·01	0·03	0·20	67·2	65·8	54·6	54·6
		19 „	90·25	29·40	5·74	1·12	1·0640	0·9240	0·3262	0·1932	7·2562	5·1431	1·6191	0·6757	0·06	0·03	0·03	0·20	71·4	67·2	65·8	64·4
		Totals	1392·95	600·60	148·16	46·62	36·1946	25·9896	10·5697	6·1096	220·1967	170·0768	67·5638	21·6767	1·31	1·31	1·71	9·29	2115·4	2065·0	2020·2	2023·7
		Averages	48·03	20·71	5·11	1·60	1·2481	0·8962	0·3644	0·2106	7·5929	5·8647	2·3297	0·7474	0·045	0·045	0·059	0·32	72·94	71·21	69·66	69·78
Percentages of purification on Crude Sewage			—	56·88	89·36	96·66	—	28·19	70·80	83·12	—	22·76	69·31	90·15	—	—	—	—	—	—	—	—

SEWAGE EXPERIMENTS AT BEAUMONT LEYS FARM.

PROCESS No. 15, viz. : 1—Crude Sewage. 2—Closed Detritus Tank. 3—Septic Tank. 4—Clarifying Bacteria Bed No. 1. 5—Fine Bacteria Bed. Quantities stated in grains per gallon.

Duration of Process.	No. of Times Beds Filled per Day.	Date Analysis Taken.	Suspended Matters.					Albuminoid Ammonia.					Oxygen Absorbed at 80° F. in 4 hours.					Nitrogen as Nitrates.					Matters in Solution.				
			Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed 2nd Contact.	Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed, 2nd Contact.	Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed, 2nd Contact.	Crude Sewage	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed 2nd Contact.	Crude Sewage.	Closed Detritus Tank.	Septic Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed 2nd Contact.
1899																											
20 July to 2 Sept.	3	26 July -	60·90	No Analysis	11·34	6·02	1·68	1·2110	No. Analysis	0·4858	0·3738	0·2576	7·5684	No Analysis.	3·1500	1·5632	0·7924	0·03	No. Analysis.	0·03	0·03	0·49	74·2	No Analysis.	60·9	60·2	58·1
		2 Aug. -	33·50	„	10·22	3·08	No. Analysis.	0·8190	„	0·4900	0·3052	0·2100	6·5815	„	2·9930	1·4844	0·6074	0·03	„	0·03	0·03	0·38	65·8	„	65·1	68·6	72·8
		16 „ -	22·40	„	9·10	4·76	0·84	0·8624	„	0·4116	0·3248	0·1433	5·8719	„	3·1977	1·4704	0·6395	0·03	„	0·03	0·03	0·57	74·9	„	60·9	60·9	60·2
		23 „ -	10·50	„	11·48	5·32	2·52	0·9961	„	0·6388	0·3499	0.2220	7·9808	„	5·8721	2·2727	0·8468	0·03	„	0·03	0·06	0·48	89·6	„	75·6	77·7	74·2
		30 „	51·80	„	10·08	3·78	1·54	1·1585	„	0·6888	0·4340	0·1806	8·0736	„	4·8025	2·3423	0·8199	0·01	„	0·03	0·04	0·44	71·4	„	68·6	65·8	70·0
	Totals - -		181·13	„	52·22	22·96	6·58	5·0470	„	2·7150	1·7877	1·0135	36·0762	„	20·0153	9·1330	3·7060	0·13	„	0·20	0·19	2·36	375·9	„	331·1	333·2	335·3
	Averages -		30·83	—	10·44	4·59	1·64	1·0094	„	0·5430	0·3575	0·2027	7·2152	„	4·0031	1·8266	0·7412	0·026	„	0·04	0·038	0·472	75·18	„	66·22	66·64	67·06
	Percentages of Purification on Crude Sewage - -		—	—	71·64	87·53	95·54	—	—	46·205	64·58	79·91	—	—	44·51	74·68	89·72	—	—	—	—	—	—	—	—	—	—

SEWAGE EXPERIMENTS AT BEAUMONT LEYS FARM.

PROCESS No: 17, viz.: 1.—Crude Sewage. 2.—Closed Detritus Tank. 3.—Clarifying Bacteria Bed No. 1. 4.—Fine Bacteria Bed No. 1. 5.—Fine Bacteria Bed No. 2.
Quantities stated in grains per gallon.

Duration of Process.	No. of Times Beds Filled per Day.	Date Analysis Taken.	Suspended Matters.					Albuminoid Ammonia.					Oxygen Absorbed at 80° F. in 4 hours.					Nitrogen as Nitrates.					Matters in Solution.				
			Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1. 2nd Contact.	Fine Bacteria Bed No. 2. 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.
1899:																											
19 Sept. to 13 Oct.	4	20 Sept.	20·65	16·10	3·64	1·40	0·56	0·9780	0·7630	0·3360	0·1946	0·1862	6·4358	6·0130	2·7104	0·7422	0·3638	Nil	0·03	0·09	0·64	0·76	70·0	68·6	65·8	67·2	68·6
		27 „	29·75	14·00	3·64	2·10	0·42	0·8645	0·8470	0·3336	0·2002	0·1694	6·8955	5·5720	3·2982	0·7450	0·6406	Nil	0·06	0·06	0·[illegible]	0·76	79·8	70·0	68·6	78·4	70·7
		4 Oct.	34·65	16·10	5·04	0·98	0·14	1·0465	0·7560	0·4368	0·1848	0·1722	7·4984	4·6526	2·1646	0·8484	0·5684	0·03	0·03	0·01	0·06	0·48	67·2	60·2	61·6	70·0	64·4
		11 „	70·00	18·90	5·74	1·26	0·84	2·5725	1·7920	0·4508	0·2772	0·1960	10·4342	7·0700	3·8379	0·9560	0·6419	0·03	0·03	0·06	0·22	0·60	74·2	72·8	74·2	77·0	75·6
Totals - - -			155·05	65·10	18·06	5·74	1·96	5·4565	4·1580	1·6072	0·8568	0·7238	31·2639	23·3076	12·0111	3·2916	2·7147	0·03	0·15	0·22	1·62	2·60	291·2	271·6	270·2	292·6	279·3
Averages - - -			38·76	16·27	4·52	1·43	0·49	1·3641	1·0395	0·4018	0·2142	0·1810	7·8160	5·8269	3·0028	0·8229	0·6757	0·015	0·037	0·055	0·405	0·65	72·8	67·9	67·55	73·15	69·82
Percentages of purification on Crude Sewage.			—	58·02	88·34	96·31	98·74	—	23·79	70·54	84·29	86·74	—	25·45	61·58	89·47	91·32	—	—	—	—	—	—	—	—	—	—

WATER CAPACITIES OF CLARIFYING BACTERIA BEDS.

Total Capacity of four Clarifying Bacteria Beds = 19,978 cube feet = 124,862 Gallons.
Mean Approximate Area - ditto - ditto = 493 Square Yards.
Depth of ditto - ditto = 4 feet 6 inches.

Date Capacity Measured.	No. of Fillings.	No. of Days since last Measured.	Total Water Capacity of the Four Beds in Gallons.	Percentages of Increase or Decrease in Water Capacity.	Percentages of Water Capacity compared with Total Capacity.	Volume treated per Cube Yard per Day.	Volume per Acre 1½ Yards Deep of Beds per Day.	REMARKS.
1898.								
24 September - -	3	—	61,865	- - -	49·54	250·83	1,822,068	
15 October - -	3	21	59,066	4·52 decrease -	47·305	239·48	1,739,631	
21 December - -	3	67	49,795	15·69 ,, - -	39·88	201·89	1,466,577	
1899.								
17 January - -	3	27	45,052	9·52 ,, - -	36·08	182·66	1,326,885	
2 February - -	3	16	44,459	1·31 ,, - -	35·60	180·26	1,309,419	
16 ,, - -	3	14	43,211	2·80 ,, - -	34·60	175·20	1,272,663	
3 March - -	3	15	45,432	5·14 increase -	36·38	184·20	1,338,078	7th. Filling, after 3½ days' rest.
15 ,, - -	3	12	44,620	1·79 decrease -	35·73	180·91	1,314,162	
29 ,, - - -	3	14	43,051	3·51 ,, - -	34·47	174·55	1,267,950	
10 April - - -	3	12	48,238	12·04 increase -	38·63	195·58	1,420,719	1st. Filling, after 10 days' rest.
13 ,, - - -	3	3	43,342	10·15 decrease -	34·71	175·73	1,276,521	10th. ,, ,, 10 ,,
26 ,, - - -	3	15	42,896	1·02 ,, - -	34·35	173·92	1,263,387	
11 May - - -	3	15	42,396	1·16 ,, - -	33·95	171·89	1,248,660	
17 ,, - - -	3	6	41,859	1·31 ,, - -	33·50	169·64	1,232,256	
30 ,, - - -	3	13	48,572	16·09 increase -	38·90	196·93	1,430,556	1st. Filling, after 12 days' rest.
31 ,, - -	3	1	45,178	6·98 decrease -	36·18	183·17	1,330,596	4th. ,, ,, 12 ,,
14 June - - -	3	14	42,563	5·78 ,, - -	34·06	172·57	1,253,577	
29 ,, - - -	3	15	41,839	1·69 ,, - -	33·50	169·64	1,232,256	
12 July - - -	3	13	41,060	1·86 ,, - -	32·88	166·47	1,209,315	
27 ,, - - -	3	15	40,282	1·89 ,, - -	32·26	163·32	1,186,398	
10 August - -	3	14	42,730	6·08 increase -	34·22	173·25	1,258,497	4th. Filling, after 3½ days' rest.
24 ,, - - -	3	14	41,506	2·86 decrease -	33·24	168·29	1,222,410	
7 September - -	3	14	39,391	5·09 ,, - -	31·54	159·71	1,160,154	Heavy rains whole of 16 hours previous to test.
20 ,, - -	4	13	36,331	7·76 ,, - -	29·09	196·40	1,426,696	6th. Filling, after 3½ days' rest.
4 October - -	4	15	35,107	3·36 ,, - -	28·11	189·79	1,378,644	
6 November - -	4	33	44,232	25·99 increase -	35·42	239·12	1,736,976	1st. Filling, after 24 days' rest.
6 ,, - -	4	—	40,504	8·42 decrease -	32·44	218·96	1,590,580	2nd. ,, ,, 24 ,,

SEWAGE EXPERIMENTS AT BEAUMONT LEYS FARM.

PROCESS No: 17, viz.: 1.—Crude Sewage. 2.—Closed Detritus Tank. 3.—Clarifying Bacteria Bed No. 1. 4.—Fine Bacteria Bed No. 1. 5.—Fine Bacteria Bed No. 2.
Quantities stated in grains per gallon.

Duration of Process.	No. of Times Beds Filled per Day.	Date Analysis Taken.	SUSPENDED MATTERS.					ALBUMINOID AMMONIA.					OXYGEN ABSORBED at 80° F. in 4 hours.					NITROGEN AS NITRATES.					MATTERS IN SOLUTION.				
			Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1. 2nd Contact.	Fine Bacteria Bed No. 2. 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.	Crude Sewage.	Closed Detritus Tank.	Clarifying Bacteria Bed No. 1.	Fine Bacteria Bed No. 1, 2nd Contact.	Fine Bacteria Bed No. 2, 3rd Contact.
1899:																											
19 Sept. to 13 Oct.	4	20 Sept.	20·65	16·10	3·64	1·40	0·56	0·9780	0·7680	0·3360	0·1946	0·1362	6·4358	6·0130	2·7104	0·7422	0·3638	Nil	0·03	0·09	0·64	0·76	70·0	68·6	65·8	67·2	68·6
		27 „	29·75	14·00	3·64	2·10	0·42	0·8645	0·8470	0·3336	0·2002	0·1694	6·8955	5·5720	3·2982	0·7450	0·6406	Nil	0·06	0·06	0·[illegible]	0·76	79·8	70·0	68·6	78·4	70·7
		4 Oct.	34·65	16·10	5·04	0·98	0·14	1·0465	0·7560	0·4368	0·1848	0·1722	7·4984	4·6526	2·1646	0·8484	0·5684	0·03	0·03	0·01	0·06	0·48	67·2	60·2	61·6	70·0	64·4
		11 „	70·00	18·90	5·74	1·26	0·84	2·5725	1·7920	0·4508	0·2772	0·1960	10·4342	7·0700	3·8379	0·9560	0·6419	0·03	0·03	0·06	0·22	0·60	74·2	72·8	74·2	77·0	75·6
Totals - - -			155·05	65·10	18·06	5·74	1·96	5·4565	4·1580	1·6072	0·8568	0·7238	31·2639	23·3076	12·0111	3·2916	2·7147	0·03	0·15	0·22	1·62	2·60	291·2	271·6	270·2	292·6	279·3
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Percentages of purification on Crude Sewage.			—	58·02	88·34	96·31	98·74	—	23·79	70·54	84·29	86·74	—	25·45	61·58	89·47	91·32	—	—	—	—	—	—	—	—	—	—

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15 „ - -	3	12	44,620	1·79 decrease -	35·73	180·91	1,314,162	
29 „ - - -	3	14	43,051	3·51 „ - -	34·47	174·55	1,267,950	
10 April - - -	3	12	48,238	12·04 increase -	38·63	195·58	1,420,719	1st. Filling, after 10 days' rest.
13 „ - - -	3	3	43,342	10·15 decrease -	34·71	175·73	1,276,521	10th. „ „ 10 „
26 „ - - -	3	13	42,896	1·02 „ - -	34·35	173·92	1,263,387	
11 May - - -	3	15	42,396	1·16 „ - -	33·95	171·89	1,248,660	
17 „ - - -	3	6	41,859	1·31 „ - -	33·50	169·64	1,232,256	
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29 „ - - -	3	15	41,839	1·69 „ - -	33·50	169·64	1,232,256	
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20 „ - -	4	13	36,331	7·76 „ - -	29·09	196·40	1,426,696	6th. Filling, after 3½ days' rest.
4 October - -	4	15	35,107	3·36 „ - -	28·11	189·79	1,378,644	
6 November - -	4	33	44,232	25·99 increase -	35·42	239·12	1,736,976	1st. Filling, after 24 days' rest.
6 „ - -	4	—	40,504	8·42 decrease -	32·44	218·96	1,590,580	2nd. „ „ 24 „

Mr. G. J. Fowler.

7 Mar. 1901.

8409. What do you base your conclusion upon, because if I remember the only experiments you had made with chemical effluent were by the Roscoe filters. It is on that experience?—Not only these, but our experiments with settled sewage. Before we took septic tanks we worked with raw sewage and settled sewage with beds which afterwards took septic tank effluent, and we never got a non-putrefactive effluent with one contact under these circumstances, and by no means always with two, whereas now with septic tank effluent we get constantly non-putrefactive effluents with one contact and effluents of the very highest degree of purity with 1½ contacts.

8410. Then your opinion is that septic tank action is useful in promoting the changes which come about in subsequent filtration?—That is certainly my opinion.

8411. Would you mind telling us in your own words what you consider from your recent experience to be the value of septic tanks?—One of the first things in which a septic tank appears to be valuable is that it mixes the sewage as it comes down from hour to hour and produces an effluent of a much more equable composition to go on to the bacteria beds, so that these are not subject to very considerable extremes, either in the way of acidity or alkalinity, or whatever it may be, according to the material that comes down. And further what we have found in Manchester I think should be noted, and it is this, that in the septic tank apparently the process which goes on has a tendency to so disintegrate the suspended matter that it is very much more easily retained on the surface of the bed, or if it penetrates does not hold the water to the same extent. That is to say if you take a bottle of crude sewage, or even of simply settled sewage, the suspended matter floats about in it in a sort of emulsion, and does not show any tendency to settle; if, on the other hand, you take septic tank effluent it may be very black in appearance, worse perhaps at first sight than settled sewage, but if it is allowed to stand in the bottle for a short time all this black suspended matter settles down quite cleanly to the bottom, and leaves a fairly clear effluent to be dealt with on the bed, and this suspended matter when it gets on to the bed allows the water very readily to penetrate through it. It seems to be in the nature of a granular precipitate, which ordinary laboratory experience shows is very easily washed. It does not hold the water as anything of a gelatinous nature would do. I think that is a point that should be mentioned as the result of our experience in Manchester. And I should like to say that anything I say applies merely to Manchester sewage, because our sewage is essentially different from sewage in other places. We have not the amount of greasy material that is sometimes met with.

8412. Another advantage of the septic tank is that it digests as you suggest 25 per cent. of the suspended solids in the sewage?—That is so.

8413. And there are no chemicals to swell the volume of the sludge?—And no cost in chemicals. And then there is this, further. I think it can be shown, although our experiments at present are only very preliminary, I think we shall find that the actual chemical changes which go on in the septic tank are anaerobic changes, such as to produce compounds which are readily oxidised by subsequent treatment on the beds. I think that it is probable that it is easier to break down sewage matters by preliminary anaerobic action, followed by oxidation, than if the process is throughout one of oxidation. That is our experience.

8414. (*Chairman.*) Open and closed septic tanks?—We made that experiment. We compared the effluent from the two over a considerable period of time, and the results were practically identical.

8415. (*Professor Ramsay.*) There is one more point. The last witness we have had to-day told us that his experience at Leicester corroborates a remark which is made by the Philadelphia Sewage Report, namely, that if the action does not go on too long in the septic tank, the effluent from it is more easily oxidised than if the septic tank action goes on to an end. Has Mr. Fowler made any experiments in connection with that?—I have no definite results on that head. We are rather of opinion from a few isolated observations that we have made—for instance, the filtration of septic tank effluent after it has been standing quiescent over the week end, that very probably you can allow the septic action to go too far, that the effluent becomes foul, and it does not subsequently oxidise as readily. I think that that is quite probable, but I have no very definite evidence to give on the subject.

8416. (*Colonel Harding.*) The point is material, because it affects the rate of flow, does it not?—Certainly.

8417. You have told us that your results were obtained from a flow which would fill the tank in 12 hours. Is not that so?—Yes, that is so.

8418. And it is interesting to know whether it is better to have that rate of flow or one very much slower?—Certainly. We have, of course, directed our experiments rather to see what we could do with the plant we have at hand.

8419. (*Professor Ramsay.*) Had the open septic tank a 12 hours' flow to commence with?—Probably it may be taken that it was a 12 hours' flow from the commencement, because, unfortunately, we ran the tank rather fast at the beginning. The rate of flow at the beginning was rather greater than it recently became.

8420. Then you state that the suspended matter entering the tank was 26 grains. How was that determined?—Simply by weighing on a filter paper.

8421. Did you take any account of colloidal substances that could pass through the filter?—No, we have merely taken what remains on the filter paper.

8422. Have you any idea of the weight of the gas evolved from the tank? Have any experiments of that kind been made?—Of course we can calculate the weight from the volume.

8423. Has that been done?—We calculated, as far as I recollect, that about 50,000 cubic feet of the gas that we got, that was evolved from the tank, made one ton. I am speaking now simply from memory.

8424. And what amount of the 26 per cent. of the solids digested would this gas represent?—That I could not give you on the spur of the moment, but we did make that calculation, and it did not account for the whole of the solids digested. Certainly I can say so much.

8425. Was it a very large proportion of it?—Not a very large proportion of it, if I recollect aright.

8426. It would be interesting to go into that point, would it not, to see how much of the solids disappear as gas, and how much disappears as soluble matter?—I may say further there is some difficulty in our case where this point has come up, and we have thought it over, and we are going to make some further determinations. One way of working would be to determine the total dissolved solids in the sewage as it enters and the sewage as it goes away.

8427. That is the next question I was going to put to you. Have you made any determinations of the solids in solution?—We have made a few, and to our surprise there were apparently fewer dissolved solids in the effluent than in the sewage, and our only explanation of that was that a certain deposit of lime had taken place in the tank. There are large quantities of lime salts in Manchester, and that seemed to make the research very difficult.

8428. That is to say that the solids which had been digested, and had therefore gone into solution, were counterbalanced by a quantity of lime depositing without solution?—That was our provisional hypothesis, but I may say we are going on with the process.

8429. (*Colonel Harding.*) Would there not be a deposit of iron?—Yes, no doubt.

8430. So that iron would also have to be added to the lime?—Yes.

8431. (*Professor Ramsay.*) Have you ever thought of warming a septic tank by waste steam?—No, it has never entered into our calculation.

8432. Have you noticed any difference between summer and winter working?—No; as far as the purification of the sewage goes, the difference that we have found is simply in the amount of recovery which takes place in the beds during the periods of rest, and that appears to be less in the winter than in the summer.

8433. I am speaking of the septic tank, not of the beds. Does the action appear to go on more or less fast in the summer than in the winter, or have you any data?—I have no data. Speaking from ordinary observation I should think it would go on rather faster in the summer. It does not seem to be very much faster.

8434. (*Colonel Harding.*) Do you not think that if you kept it at a temperature of 80 degrees you would get more active septic conditions?—No doubt it could be kept to that, but the smell is not much greater in the summer than in the winter.

8435. (*Professor Ramsay.*) You said the digestion in the tank was best during cold weather?—No; I said I did not notice any very great difference. In these experiments of ours the two periods that we took the observations in were: First, from May 16th to November 14th, and then again from November 14th to January 24th. Those are hardly comparable, because in one case the tank was starting, and in the second case it had got to its full activity.

8436. (*Dr. Russell.*) With reference to these deposit chambers that you are constructing in the septic tank, I did not quite follow the process by which you return the deposit from the outlet to the inlet again so as to give it a chance of being digested. Further, is it automatic, or does it involve labour?—We do not propose to return that deposit to the tank, therefore it will be taken actually away. We assume that when it has attained such an amount as that at the far end that it will to a considerable extent have been disintegrated. We have made no provision for returning it actually to the tank, although I may say it would be quite easy to do so by the pumping apparatus by which we can easily pump it back, and treat it to any extent. There would be no difficulty whatever.

8437. It is the labour involved, it is important that it should be done, but it is a question of labour. You have told us something about a pipe beneath the tank communicating between the two?—There would be no labour other than the opening of the valve, because we imagine that the weight of the water will force itself through to the required extent. If it should not be so it will be easy to run off the water by a floating arm, and put men in who will quickly push it through the pipe. Then it will run down a channel, and will easily be sent away to sea, or it can be pumped back into the treatment, and go through the thing again without any difficulty whatever.

8438. (*Mr. Killick.*) I think you expressed the opinion that your septic tanks should be capable of containing twice the daily flow?—I said that the results which we have obtained are got on tanks having a capacity equal to half the daily flow.

8439. Yes, but looking forward to the treatment at five times the volume of the daily flow, you recommend tanks that will hold twice the daily flow?—But I would not propose to treat five times the volume of the daily flow by septic action.

8440. If you received five times the daily flow, will you put it through on septic tanks?—Oh, no, not all of it.

8441. Not all of it?—Oh, no.

8442. (*Colonel Harding.*) How would you deal with it?—We should pass it through settling tanks and start on the storm bed.

8443. (*Mr. Killick.*) Then your settling tanks of what capacity do you propose those should be?—There will be four of them altogether of the united capacity of something like 6,000,000.

8444. And the storm flow which is turned into these settling tanks, the sewage itself would be in a septic condition after passing through your sewers?—Hardly.

8445. Hardly?—In the case of a storm it would come down so fast that it would be practically fresh sewage; in fact, the sewage when it gets to the works now, although it is to some extent disintegrated, is yet fresh as compared with what we get from the septic tank.

8446. Then your storm waters which will be turned from these septic tanks will not undergo any septic action?—No. One provision which we have made has been rather carefully directed to the end that we shall not put septically treated sewage on to our storm beds. That seems to me of importance, because we have found unmistakably that if a bed has been used to septic sewage it will not at once purify fresh sewage, and *vice versâ*, therefore it is important that anything which is turned on to the storm beds should be fresh, and I propose to keep them in action by giving them a daily dose of ordinary settled sewage just to keep them going.

8447. And you would rather say that beds accustomed to septic sewage will not be efficient for non-septic sewage, and *vice versâ*, rather than that septic sewage is not suitable for treatment on a filter bed?—Certainly.

8448. It is the change?—The change, yes. I think that that is a point which it is important to emphasise because we have noticed that very frequently.

8449. (*Colonel Harding.*) Then the other point that we now reach, Mr. Fowler, is this as to the possibility of maintaining capacity in contact beds when dealing with septic tank effluents from which you have withdrawn as much of the suspended solids as you found to be practicable. Now, since we had the advantage of examining you in Manchester you have had additional experience of some nine months, and therefore we are very much interested to hear from you how far you have been able to maintain the capacity of your beds. I notice that on page 1 of your report you speak to us about the little Roscoe beds, and you tell us that they have been working for five years, but that they have recently reached a condition when it became necessary to wash out a certain portion of the material. I think some 12 or 14 inches of it, was it not?—That was so.

8450. The sewage did not pass down any longer and the time came when something had to be done, and you washed that part of your beds, and by such washing have restored a considerable portion of their capacity?—Yes.

8451. But those Roscoe beds, I think, have been working during the whole of that period with the effluent from chemical precipitation, an effluent which I think Sir Henry Roscoe told us only contained about 3 grains per gallon of suspended matters?—That is so.

8452. So that they really have been worked very little indeed in regard to suspended matters, and the experienc with the Roscoe filters would scarcely be a guide to you for the dealing with a septic tank effluent containing 11 grains of suspended matter?—Not entirely.

8453. Then I will not spend time about the Roscoe filters, nor indeed ask you any questions as to the way you have been working these various beds. You gave us very full information before, but with regard to your beds *a*, *b*, *c*, *d*, which are the experimental beds advised by your experts, I see that you give us certain information. (*See* tables, pages 815-823.)

8454. Now the information that you give us covers four or five pages and is voluminous, and no doubt is useful, but I have endeavoured to extract from it a condition at the beginning and the end of the periods and to select conditions which would make the comparison a fair one. Now take bed *a*. I find that in June, 1900, the capacity with one week's rest and one filling and six hours' draining was 2,490 gallons?—Yes.

8455. Then I find that in February, 1901, bed *a* with one week's rest, one filling, and six hours' draining, that is the same conditions that I named before, had a capacity of 1,910 gallons?—Yes.

8456. Now we take bed *b*. I find that *b* in June, 1900, after one week's rest, one filling, and 1¼ hour's draining had a capacity of 3,200 gallons?—Yes.

8457. The same bed in January, 1901, after seven days' rest, one filling, and 1½ hour's draining, had a capacity of 2,780 gallons?—Yes.

8458. Bed *c*, on the 29th of June, 1900, after one week's rest, one filling, and six hours' draining, had a capacity of 2,480 gallons; and the same bed on the 17th of January, 1901, with one week's rest, one filling, six hours' draining, had a capacity of 2,230 gallons?—Yes.

8459. Then, finally, bed *d* had on May 17th, 1900, after two hours' draining, 2,380 gallons capacity; same bed September, 1900, after one week's rest, one filling and 2½ hours' draining had a capacity of 2,130 gallons. Now, adding together those four initial capacities at the earlier dates, I find that the total capacities at those times of these four beds is 10,550, and adding together the final capacities of the four beds they amount to 9,050 gallons, and show, therefore, that for the four beds, there has been an average reduction of 13 per cent. in about six months; is that a fair way of putting it, Mr. Fowler?—There has undoubtedly been a certain amount of loss of capacity, but I think it is only fair to note that the earlier measurements were made in the summer time, and these latter measurements made in the winter time. You will notice in the case of the last measurement of *a*, the snow was on the surface of the bed almost all the rest week, and that we have certainly found has been that you do not get the same value for your periods of rest in the winter. If you give a bed a week's rest in the winter it does not seem to recover itself to anything like the extent that it does in the summer. And, perhaps, I might refer you to previous observations of capacity during the former winter, and then, I think, it will be seen that comparing winter capacity with winter capacity the capacities now are actually greater considerably than they were at that time.

8460. And the fact of your having lost 12 per cent.

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capacity in the last six months does not cause you any alarm in view of the circumstance you have mentioned that you are comparing winter with summer capacities?—I hope, I think, with some amount of reason that in the summer we shall more than recover that amount that has been lost.

8461. Against this reduction is to be set the fact that in the filter beds connected with your Cameron plant you have showed that there had been an actual increase of capacity in these beds after six months' work?—That is so. I was particularly careful about these measurements. They were made more than once; one made in January, and another in February, because it seemed to me rather extraordinary that it should be so, but I can see no reason for doubting their accuracy.

8462. And there has been no removal of the surface or of matter on the surface of those beds?—Not of those beds. Of some of the beds it has been so.

8463. But you would expect on continuous working of contact beds with septic effluent that there would be a gradual, though it might be a very slow, reduction of capacity?—Well, I am not prepared to grant that at once, because there will undoubtedly be an initial and pretty rapid reduction, but on examining these beds we find that there is a very marked difference between the first six inches and the material below. The first six inches is just like ordinary black soil, underneath that the cinders are perfectly loose. If you put a fork in they fall apart, and there seems to be no tendency for them to bind together into a solid mass. What I do think is possible is that there might be a slight disintegration if the material is not very good. We have found for instance, in washing out the Roscoe beds that a great proportion of what you washed out was actually fine pieces of clinker, and that in process of time there may be this certain amount of disintegration and settling of the bed, but if you are very careful to get hard material to begin with, that, I think, should be reduced to a minimum, and if this decrease of capacity was an absolute decrease it seems to me extraordinary that you should be able to recover it at all, because if the space is not actually there you could hardly imagine that you could get it back again, whereas, as I say, taking the measurements a year ago, they are now actually more than they were at that time.

8464. In those particular beds, in the beds connected with the Cameron?—In the Cameron beds, and also in these.

8465. In *a*, *b*, *c*, *d*?—I might, perhaps, just refer to the results I gave previously. You will find, I think, here on March 1st, 1900, *a* bed was measured after 3½ hours, and gave a capacity of 1,940, which is very much the same as it gives at present, and on April the 11th, 1900, the capacity had gone down as far as 1,480, and it is now 1,900. And again, *c* bed, on April 3rd, 1900, was 1,570, and it is now 2,780.

8466. Then we may take it, Mr. Fowler, that in your experience over the whole period, notwithstanding the changes, rises and falls of capacity, the capacity has been fairly maintained working with septic tank effluent?—Working with septic tank effluent the figures show that the capacity has been fairly maintained throughout that period.

8467. And in the new beds which you are proposing to lay down, which, I think, you are actually laying down, you are endeavouring to arrest on the surface of the bed as much suspended matter as you can by using fine screened material as the top layer of the material?—Yes.

8468. And the experience you have had since we examined you nine months ago does not lead you to change your opinion on that point?—No, I have not changed it.

8469. You have a single filter bed; I think you call it a cinder screen bed?—Yes.

8470. On which you have been using chemical effluent at a rate of half a million gallons per acre, and getting good results. I see in that case you have been getting a bright filtrate with no suspended matter?—That is so.

8471. And, therefore, there would be some reduction of capacity; you do not say anything about the reduction of capacity, but if it is only small, we need not inquire into it?—I think not.

8472. You have a rough cinder bed. This has some interest for us, because you are using it as a storm bed?—Yes.

8473. I understand you have had no washing, cleaning of that bed, or any removal of accumulations upon it, all that you have done to it recently is to rake it over?—That is all that has been done.

8474. And that it has been working for six months with two fillings a day during time of dry weather flow—two fillings of what?—Of chemical effluent.

8475. And when there has been a highly dilute sewage, you have been streaming such dilute sewage continuously over it at the rate of 2½ million gallons per acre?—That is so.

8476. And you have not found any choking to arise, at least not to the extent of preventing the sewage going down into the bed?—None, whatever.

8477. In fact, so far as you have been able to judge after a week's rest the bed is in working order?—That is so.

8478. And you state in your report the filtrates are for the most part non-putrescible?—Yes.

8479. An interesting point to ascertain would be whether it is better to use a shallow than a deeper bed, and this 15in. bed seems to have given you very good results?—My own feeling would be that if you had acreage enough it would be advantageous to do so. The bed drains so rapidly, and you get it very easily aerated, and certainly my own preference would be for shallow beds supposing you had a sufficient area of land.

8480. But then the highly dilute sewage which you have been streaming over this particular bed would not contain much suspended matter?—At times it contains a fair amount.

8481. Did you find as much suspended matter come out of so shallow a bed?—A small amount would, and when we had very rough storm water going on naturally the filtrates were muddy and opalescent, but they did not contain an excessive amount of suspended matter.

8482. And your experience in working that bed with storm waters, and of a shallow depth of 15 inches, has been encouraging?—Very encouraging; I might say that immediately round the inlet, as you would naturally expect, there is a certain amount of accumulations of silt over the surface, but it is quite easy just to push that aside with the spade, and the clinkers underneath are quite good, and at the far end on taking up the bed the cinders are quite crisp. Of course in this particular case the sewage was rushed on to the bed by one penstock at one particular point, and all the suspended matter appears to have collected just round there.

8483. (*Chairman.*) I should just like to ask you one question about these beds at Friern Barnet and Clifton Junction; these beds you say have been working satisfactorily for such a long period as ten years?—That, I believe to be the fact; I am told so with reference to Friern Barnet, and I know the engineer very well of the Clifton Works.

8484. But you have not taken measurements there yourself?—Oh, no; it is simply information which has been conveyed to me.

8485. You say that a bed may maintain, practically speaking, a constant capacity?—That is so; a constant average capacity, I would prefer to say.

8486. Well, that constant average capacity will not be its full capacity at the starting point?—Oh, no.

8487. And about what proportion should you say was a possible constant capacity?—Well, I think one would be safe in saying from 25 to 30 per cent, of the total water capacity of the tank. That is how we have usually calculated it.

8488. (*Major-General Carey.*) Of the gross capacity?—Of the gross capacity.

8489. (*Mr. Killick.*) Before you put your cinders in?—Before you put your cinders in. For instance, you see before putting the cinders in, these tanks would hold some 10,000 gallons, and even as we have worked them, and it must be borne in mind too that these figures are for periods of forcing and various experiments done with other ends in view than merely maintaining the capacity, it seems that we can at any rate keep the capacity up to 2,500, that is 25 per cent. you see, and in some cases more than that, perhaps even more than 30 per cent., but I think one would be safe in saying from 25 to 30 per cent.

8490. (*Chairman.*) But does it not seem to you a very remarkable thing that you should lose three quarters of the capacity and maintain one quarter?—That is how it works out. Why it should happen to be just that figure I can hardly say. Of course, the reduction of capacity is due in the first place undoubtedly to the consolidation of the material. When it is first put in

it is quite loose, and by working it it works itself together, and one piece sets into another, and then one notices on cutting down a bed that there is a shining jelly all over the cinders. If the bed is in good condition there should be very little blackness, but just this gelatinous appearance, which fills up the interstices, and in my mind when that condition has set in the capacity is of necessity you may say more or less constant, because very little more can get in. Any decrease of capacity appears to be very largely due to imperfect drainage, to possibly too great an accumulation of those organic growths retarding the drainage of the water from the bed.

8491. But you do not think it is only a question of time. I mean that you might lose one quarter directly, a half less quickly, three quarters less quickly than that, and be a long time over the last quarter; but you do not think that ultimately you would lose it all?—I do not think that that is possible.

8492. You do not think that that is possible?—I think you might get the capacity down to such a point, I will say this, that it would no longer be economical, and then possibly you would have to take some rather severe measures; and I may say that in making estimates for the upkeep of the work in the future I have allowed for a certain amount of washing to be done at very infrequent intervals. I think it will be possible by mechanical contrivance to do that very cheaply from all the experience we have; not to wash the upper layer—most of the suspended matter will be in the upper layer, and that it would not be economical to wash; I think it would be much better to remove that, and let it recover itself, and perhaps put it back or take absolutely fresh material, because it is, of course, very cheap such a fine cinder as that, and then it may possibly answer, say, once in ten years, or some such time as that to wash the portion immediately round the inlet. What we are endeavouring to do is to combine a mechanical filter with a bacteriological filter. Instead of setting apart one particular piece of apparatus to mechanically retain our suspended matter by the construction of our beds we hope to retain it either on the top or immediately round the inlet, and we shall make it our business to stop that bed when the matter is penetrated to a sufficient extent.

8493. (*Mr. Killick.*) Might we have the figures quite clear about the capacity; I think that they are not quite clear. The total gross capacity of your tank is 10,000 gallons?—Yes.

8494. What is the total water capacity?—5,000.

8495. Then it decreases to 2,500?—

8496. (*Colonel Harding.*) Another way of putting it, which is perhaps clear, is that the capacity is reduced to half the water capacity?—Yes.

8497. And it is found to be capable of maintenance at that?—Yes.

(*Major-General Carey.*) But that is not the working capacity; it is reduced to half when it is filled. But then it goes further down to 30 per cent.

8498. (*Colonel Harding.*) No; these are the facts. The empty bed without any coke in it has a capacity of 10,000; when the coke has been put in there is a water capacity of 5,000. That water capacity of 5,000 is gradually reduced until it reaches half such capacity, namely, 2,500, and at that figure it is found to be fairly maintained, working with septic effluent. Is not that so?—That is so.

(*Major-General Carey.*) That would be 25 per cent. of the gross.

8499. (*Colonel Harding.*) It is 25 per cent. of the gross, and it is 50 per cent. of course of the water capacity?—Yes.

8500. (*Chairman.*) Quite so. The 10,000 is nothing, because the 10,000 is without any filter at all; it is really that it loses half its capacity?—Precisely.

8501. And the remaining half you think remains permanent on an average?—On an average.

8502. You have told us you only speak about the Manchester sewage, but you would be prepared, I suppose, to find that sewage of a different character might suit infinitely more than Manchester does?—I think unquestionably. I think one reason for our success has been the fact that I was describing just now that the suspended matter in our tank effluent is of a granular nature. If we had anything like an emulsion of fat which would get into the filter bed, and make a mass of greasy material inside the bed then we should be in a very different position.

8503. And you attach great importance to your material being very hard?—Certainly. *Mr. G. J. Fowler.*

8504. (*Major-General Carey.*) You said that when the working capacity has reached a certain limit there is no further breaking down of the filtering material?—I do not think so unless it is very much disturbed. I think if it is filled gradually, and only the surface raked that the material becomes coated with this slime, which acts as it were as a lubricant, and consequently there should not be very much more disintegration, unless, as I say, you have bad material. If you put in shaly clinkers of course in time those will go together, but it is certainly important you should have hard, well-fused clinkers. 7 Mar. 1901.

8505. Have you formed any opinion as to the life of filtering material, say clinker or coke?—I think it may go on almost indefinitely. As I say, I have visited this filter at Clifton Junction, and taken samples from that, and the coke was perfectly hard, and after five years the material in the Roscoe filters is as hard as ever. It shows no sign of disintegration except at the top, where it has been forked and disturbed to a considerable extent.

8506. (*Professor Ramsay.*) How many grains of suspended matter did the effluent that went on to the Roscoe filters contain?—About 3; perhaps that is an average, but sometimes in storm time I may say they often had storm water, and then it would be considerably more than that.

8507. Do you determine the sludge by evaporation to dryness or by filtering?—By filtering. We would take, for instance, a Winchester full and let it settle, and further we get the amount of suspended matter in the tank effluent with considerable accuracy by passing it through a patent mechanical filter a great many gallons of it and weighing up the suspended matter which was washed out of the filter.

8508 And in the chemically precipitated effluent about how much albuminoid ammonia and oxygen absorbed is there?—That has varied during the period of the experiment. In the early years the oxygen absorbed would be about 2, and the albuminoid ammonia perhaps about ·25. Latterly the oxygen absorbed has gone up to 5, 6, or even 7, and the liquid ammonia to perhaps——

8509. (*Mr. Killick.*) Gone up to 8 and 9?—The oxygen absorbed is there?—That has varied during the period albuminoid ammonia probably from ·3 to ·35, or even occasionally more.

8510. (*Professor Ramsay.*) Is that owing to a change in the character of the Manchester sewage?—Oh, yes; it has changed greatly.

8511. Within the last five years?—Within the last five years there have been great changes.

8512. (*Mr. Killick.*) I might state the reason that Manchester has taken the manufacturers' effluent?—Yes, large quantities of manufacturers' effluent do come into the sewers, and it is on that account that the oxygen absorbed has risen. I may say I remember the date very well when one big connection was made, and on that occasion the oxygen absorbed sprang up at once by twice.

8513. (*Professor Ramsay.*) Have you examined the mud which has accumulated in the beds during the five years?—Yes, I have examined it carefully.

8514. What is the result?—There is a certain amount of organic material suspended, and the rest is disintegrated material, as I understand, inorganic matter, consisting largely of iron, lime, silica, and alumina, and some phosphates.

8515. Do you find fibre?—Not visibly. I may say it is absolutely inoffensive; it dries down very readily. There is no kind of offence about it.

8516. On page 3 is described the cinder screening bed; that is the usual bed, 15 inches deep?—Rough cinders. yes.

8517. Is that the one that takes the overflow storm water?—I am not quite sure whether you are referring to the cinder screening bed or to the rough cinder.

8518. The cinder screening bed?—The cinder screening bed has only taken precipitated tank effluent.

8519. It passes into the rough cinder bed; it is a triangular shaped bed?—Yes, in the corner of one of the land filters.

8520. I remember it. Do you distribute the storm water on to that in any way or simply run it through?

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—It is simply allowed to enter the bed by one of the ordinary penstocks. Just where the force of the water comes, we have put down a few ordinary setts to prevent the material being washed about, and it simply finds its way into the bed, and if we are streaming you have, of course, a sort of lateral filtration.

8521. Did you deal with the first flush of the storm water on that bed or only the after runnings?—I should say in many cases with the first flush. The instructions that I gave were that as soon as chemical precipitation was stopped the water should be turned on to this bed. Of course, when we get a vast quantity of storm water coming down it is futile to add a few grains of lime and copperas, and when that took place then the instructions were to work this storm bed.

8522. I suppose the bed is a very cheap one?—Very cheap indeed.

8523. Do you think such a bed would serve any good purpose to purify the sewage of a small country place?—It is just the sort of bed that I would recommend.

(*Colonel Harding.*) In that case would not there be a tank that would be simply for the slop water?

(*Professor Ramsay.*) I meant to take all the sewage.

8524. (*Mr. Killick.*) Is it not very similar to the fine bed which they are using for light sewage?—I may mention that we are using this very bed for purifying ordinary tank effluent, and it purifies it without exception.

8525. (*Professor Ramsay.*) You mentioned that you kept it efficient by always putting some sewage on?—Yes.

8526. (*Colonel Harding.*) If you are to use it for the household sewage you would get the fæces and paper and so on in its almost unbroken condition?—I do not quite understand—of course, always with an intercepting tank.

8527. In conjunction with an intercepting tank you think this bed could be used?—Oh, certainly, but I would not——

8528. (*Mr. Killick.*) A septic tank or a settling tank?—Well, there must be a septic tank.

8529. (*Colonel Harding.*) Following Professor Ramsay's inquiry about the applicability of a shallow bed to household sewage, how would you work that? You would use a septic tank, and then an overflow which would flow very gently would be put upon this bed in what way so as to fill it, or to trickle over it, or how?—I think it would be a satisfactory plan if you cut grips in the surface and allowed it just to flow gently over.

8530. So as to fill it?—Well, I would have the outlet partly open, so that it should not go straight through the bed, but would be to a certain extent held up while the bed was in action; I think some such device as that.

8531. Its action would be intermittent?—There must be some sort of intermittent action about it certainly.

8532. So that it would require attention?—Quite so.

8533. (*Professor Ramsay.*) Can you tell me if the effluent that ran off that bed was ever putrescent?—Under the recent conditions of working it was very seldom putrescent, scarcely ever. We had one or two bad effluents, and then we gave it a week's rest, and then it was all right again.

8534. (*Major-General Carey.*) How is the tank effluent distributed on the filters in Manchester?—At present we find that it distributes itself quite well by the semi-circular weir which we have devised. I may say that the engineer, Mr. Wilkinson, has spent a good deal of time in devising a special apparatus for distributing the tank effluent on to these beds, and it has been his endeavour to have as few penstocks to open as possible, and with that object in view he has admitted the effluent over a semi-circular cill or weir. This forms a rim on a shallow reservoir, which is connected with the supply channel by two penstocks, so that on opening these penstocks the tank effluent fills this shallow reservoir and spreads in a thin sheet over this semi-circular cill, and so across the bed, and at present that is all we do. We find it simply spreads over the bed in a thin sheet and finds its way in. I am not at all sure that we may not find it better to cut grips in the surface, and these grips would become clogged with the suspended matter, and the intervening spaces will readily take the air when the bed is empty, but at present we are simply putting it on on a thin sheet over the surface, and it seems to work very well.

8535. (*Chairman.*) Does it cover the whole surface?—No.

8536. It never spreads over the whole of the surface?—It has done so in one case. I may say that in our initial experiments, in order to see if we could fill those beds in half an hour, we forced our septic tank by putting sewage through. That had the effect, unfortunately, of driving a very large amount of suspended matter on to the bed, and with it a good deal of grease, and that formed a thin skin over the surface, and then the water spread right over the surface, and some difficulty was experienced in getting it down, but we thought that was not fair treatment, although I was not altogether sorry it had happened, so that we can at once tell the sort of difficulty we might have in the future. Now we have raked the surface and put the water on a little more quietly we have had no difficulty.

8537. (*Major-General Carey.*) And how long does it take to fill the bed under those circumstances?—We can fill it in half an hour.

8538. Under the new arrangement you mentioned?—Oh, yes.

8539. (*Colonel Harding.*) On fine material, to act as a mechanical filter in the top?—Yes.

8540. Is there not a danger of that getting washed down into the coarser material too?—It does not seem to be so; from our experience of the other beds it seems gradually to pile itself up. Of course, the material below is not very coarse. The material below contains cinders, which have been retained on ¼in. mesh. That is to say, we took anything from 1½in. to ¼ from which to make the main bulk of the bed. I think, I am speaking tentatively from the small amount of experience we have had with these beds so far, but I think possibly it would not be altogether wise to make a top layer entirely of fine material. It is a question of detail, but it seems something like this, that if you have it entirely of fine material you get a perfectly——

8541. Water-logged surface?—You tend to, because you have a perfectly level sheet over which you can have a thin skin of clogging matter, whereas if you have a certain amount of intermixed rougher material your surface is very greatly multiplied, and the tendency to clogging is very much reduced. I may say with our experimental beds, which take the water with the greatest ease, we never have any difficulty of that sort at all. It is remarkable to me that it should be so, but it is a fact that when we have got 6in. of soil on the top they take the water quite readily, only it has to be noticed that that soil is intermixed with a considerable proportion of rougher clinker.

8542. Is there not a danger round your semi-circular cill of that fine material on the top being washed forward, and so the lower portion is bared?—That happens to a very small extent so far as we can say. Of course, I quite expect to get a certain amount of accumulation of suspended matter close to the cill, and I rather hope it will take place there, because we can then take it out just round at that point.

8543. (*Professor Ramsay.*) Could you tell us approximately how fine the material on the top of the bed originally is when you are making the bed?—What we do is simply this. In making the bed we first of all collect by hand the rough big pieces of clinker which fall to the bottom of the tip. You always find that the big pieces fall to the bottom, and those we take to pile over the drains to improve the drainage. Then the remainder is put through a screen of about ¾in. mesh. Practically that would retain a good deal which is below ¾, but everything which passes that screen is put on the top, or else is used for making concrete.

8544. Then this clogged layer, which prevents the very fine matter getting into the bed varies from ⅜ths of an inch down to a grain of sand, I suppose?—Yes, it contains everything below that.

8545. Have you estimated—I am talking of the experimental beds now—the solids in suspension that come in the effluent into the coarse bed, and also in the fine bed—there were a few, I remember, when I was there?—I may say that the solids are almost too small in amount to estimate in both cases.

8546. And they continue so?—They continue so, yes, and the final effluent is pretty much like drinking water as far as I can see.

8547. There is only, I think, one other point I notice that if you take the quarter ending September 26th and the quarter ending December 26th, in the first case

the quarter is warm weather, you have 1 in 2 of the effluents in the coarse beds putrescible *a* and *c*, and in the cold weather, in the quarter ending December 26th, you have only one in 16 putrescible?—Certainly.

8548. And the same thing holds good for the effluents from bed *b*, practically speaking. Was that due to the great dilution in winter, or what was it?—No, I think it admits of a simple explanation, namely, that during the earlier period our septic tank effluent did not come thoroughly into condition. That is one of the results which leads me strongly to the opinion that you require to have a thoroughly septicised effluent to get very good nitrification.

8549. It struck me as a very important point, so I wanted to know what your explanation was?—That is the explanation, because previously we found the same thing at our former running of the septic tank—at the beginning we got some bad results, and afterwards we got nearly perfect ones.

8550. One would naturally expect it to be the opposite way—that you would get less putrescent effluent in the hot weather?—Exactly, but I think that is the explanation.

8551. (*Mr. Killick.*) Just one question about this piling up of the beds?—to what do you attribute it, to the swell of the material in the bed or to the matters being thrown up from the bed?—I think it is very largely due to the actual piling up of the suspended matter in the effluent. What we have found is that this piling takes place when you have occasion to frequently rake your bed. It has taken place to the greatest extent on the surface of the closed septic tank—the Cameron installation beds, where we have had very little loss of capacity, comparatively, and those have been most frequently raked, and whenever you rake a bed it tends to loosen the surface, and to pile it to that extent, then you have some more suspended matter accumulating upon them, and you rake again, and so the thing piles up, and that is what we found in the case of the Roscoe beds after we have raked them. We have not noticed the piling in the case of these other beds, *a*, *b*, and *c*, because, as a matter of fact, we have very infrequently raked them, but latterly we have raked *a* once or twice, and the same phenomena appear to have been produced there.

8552. And when you rake this matter on the top together, do you remove it—do you intend to remove it?—Eventually, and in one or two cases we have already removed it, and eventually we shall doubtless have to, and then either we shall leave it for an indefinite period to thoroughly recover itself, and then put it back; or, as I say, we may find it cheaper to get actual fresh material, it being so easily obtainable. But I think it would be better really to put back the old stuff after a period of rest, because there is more likelihood of nitrification taking place. We have noticed one thing perhaps I ought to mention while we are speaking on this subject, because there can be no doubt about it, that after removing this top layer for a short period the nitrification goes down, showing that apparently the active nitrification takes place largely in the top layer, which is, of course, old information.

8553. (*Chairman.*) When you remove the top layer, do you replace it by a new layer of fine stuff?—In some cases; for instance, in one of the septic beds I took the top off one of them and put it aside, and then there came the turn of another bed. I took the top off that, and put the old top back again in its place, with very good results. There was no clogging of the surface at all. I think what we shall do in future will be not to remove it entirely. You see the layer, from being perhaps originally two or three inches, becomes six or eight inches. Well, you see you could remove it down to the original two inches, and keep it like that.

8554. But you would attach importance to always having a layer of fine stuff on the top?—I think so, certainly.

8555. And your experience about filters generally, I gather from what you said, is that they are more effective after they have been matured?—Unquestionably.

8556. (*Colonel Harding.*) You are now putting down a considerable area of beds?—Yes, we are now putting down five more acres in addition to the acre that we have, and we have also got plans in hand for going on with 20 more.

8557. When we visited Manchester we saw the half acre beds you are referring to being constructed. Are they at work?—They are now daily at work.

8558. How long have they been at work?—I should think regularly about a month.

8559. Scarcely matured yet?—No, but I may say that at present I am filling them once a day, and the majority of the filtrates are non-putrefactive already.

8560. What figures have you in your mind as to the volume which may be dealt with per acre upon these beds?—I think I have always in my own mind worked it out that you can effectively or efficiently purify septic effluent in Manchester at the rate of about half a million gallons per acre with careful working.

8561. On single beds, not double contact, single contact beds?—Single contact; a certain amount of double contact possibly in the future.

8562. Then is your half million gallons based on single contact, because I take it that with double contact that would reduce it to a quarter of a million?—Oh no. I take it rather in this way, that if you are beginning—for instance, if your beds are not matured, and if their capacity is not decreased you can get much more than half a million through, you can get up to a million with a high capacity, but it will not be so effectively purified, and then you will have to have recourse to double contact. But I am speaking of adequate purification, either by single or double contact, as the case may be, because we find that with the decrease of capacity you get, as I said before, increase of efficiency, so it is difficult to say absolutely, if you follow me, whether it is half a million single contact or half a million double contact. I should prefer to put it half a million gallons effectively purified at that rate, either by a single or double, as the case may be.

8563. I only want now to ask you two or three questions in connection with the small experiments you made with Stoddart's filter. That filter was a filter 6ft. deep, built up of very coarse coke, was it not—or clinker, which was it?—Mostly of clinker.

8564. It was very coarse material?—Yes.

8565. And you passed upon it the septic tank effluent?—Yes.

8566. And you have given us here an analysis, but I have not at hand an analysis of what you obtained from the same effluent when passed over a contact bed, except with regard to the Cameron. Will you tell us, was the result of the septic tank effluent passed over this Stoddart filter better or worse or as good as what you obtained by contact filtration?—We got better results with contact filtration undoubtedly, as far as the purity of the effluent is concerned. We do not pass so much through per acre.

8567. Then if you had passed through this Stoddart filter at the same rate, say half a million gallons per acre, would you expect to get better results than you found passing at this higher rate?—No doubt it would be to some extent improved.

8568. So that there are no figures before us to enable us to judge of the results that would be obtained at an equal rate with the same septic effluent over the contact bed and over the Stoddart filter; there are no figures before us at the present moment?—No; that has not been gone into.

8569. It would be rather interesting to get that?—Certainly.

8570. It would be very easy for you to obtain it by simply reducing the flow. It would be very interesting to us if you could give us this information, whether a septic effluent passing over a contact bed and passing over trickling filtration would give better or worse results?—Yes, that we could do.

8571. Will you kindly bear that in mind?—I will, certainly.

8572. (*Chairman.*) We are much obliged to you indeed?—It is a pleasure to us to do all that we can, and I am sure we owe very much to the suggestions which have been made by the Royal Commission.

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Record of Working of Bacteria Beds, Manchester.

Date.	Remarks.	Capacity in Gallons.			
		A.	B.	C.	D.
1900:					
1 May	Measured bed C. after 27 days' rest	–	–	3,100	–
1 ,,	Remeasured after 3½ hours' draining	–	–	2,460	–
3 ,,	Bed C. filled twice per day, 9 a.m. and 3 p.m., from small settling tank, 1 hour's contact allowed, the filtrate being streamed through bed D. (This continued until the open septic tank was restarted.)	–	–	–	–
4 ,,	Bed A. measured after 22 days' rest. Much rain previous day.	2,600	–	–	–
	Remeasured after 4½ hours' draining	2,330	–	–	–
	Bed D. held up for 1 hour after the first filling on this date and subsequently.	–	–	–	–
5 ,,	Bed A. receives two fillings from small settling tank, 12 noon and 6 p.m.	–	–	–	–
7 ,,	Measured bed B. after 13 days' rest. Rain previously	–	3,400	–	–
	Remeasured bed B. after 4½ hours' draining	–	3,080	–	–
8 ,,	Bed B. started on two fillings, short cycle beginning 10 a.m., ½ hour filling, ¾ hour contact, ¼ hour draining, ¾ hour rest.	–	–	–	–
15 ,,	Shoots removed from bed B., second filling missed. Grips about 6 inches deep cut in the bed, one main channel with 3 at right angles on either side.	–	–	–	–
17 ,,	Measured bed D. after 2 hours' draining	–	–	–	2,380
24 ,,	Measured bed C. after 16 hours' rest. Heavy rain previously.	–	–	2,440	–
31 ,,	Measured bed C. after 1 week's rest (? some leakage)	–	–	3,010	–
	Bed C. worked from this date on 3 fillings per day, 9 a.m., 5 p.m., 1 a.m.	–	–	–	–
1 June	Remeasured bed C. after 6 hours' rest	–	–	2,580	–
	Surface of bed A. scraped in places. Leak at inlet stopped.	–	–	–	–
7 ,,	Bed B. rested for 1 week from this date.	–	–	–	–
	Bed A. measured after 1 week's rest, 1 filling and 6 hours' draining.	2,490	–	–	–
	From this date bed A. filled three times per day, 5 a.m., 1 p.m., 9 p.m.	–	–	–	–
..	Measured bed B. after 7 days' rest	–	3,620		
	Remeasured after 1¼ hours' draining	–	3,200	–	–
	From this date bed B. worked on 3 fillings per day, short cycle 10 a.m., 12.30 p.m., 3 p.m.	–	–	–	–
21 ..	Bed C. rested for 1 week from this date.	–	–	–	–
28 ,,	Measured bed C. after 7 days' rest	–	–	3,020	–
	Bed A. rested for 1 week from this date.	–	–	–	–
29 ,,	Measured bed C. after 6 hours' rest	–	–	2,480	
30 ,,	Bed A. lightly raked in tight places.	–	–	–	–
5 July	Bed B. rested for one week.	–	–	–	–
	Bed A. measured after 7 days' rest, heavy rain previously	2,660		–	
6 ..	Measured bed A. after 7½ hours' rest	2,280	–	–	–

Record of Working of Bacteria Beds– *continued.*

Date.	Remarks.	Capacity in Gallons.			
		A.	B.	C.	D.
1900:					
12 July	Measured bed B. after 7 days' rest	–	4,150	–	–
	Remeasured after 1½ hours' draining	–	3,510	–	–
13 ,,	Top 3 inches removed from bed B., replaced by material formerly on bed D.	–	–	–	–
14 ,,	Alterations to bed B. continued.	–	–	–	–
16 ,,	Bed B. restarted.	–	–	–	–
26 ,,	Measured bed C. after 7 days' rest	–	–	3,360 ?	–
27 ,,	Remeasured bed C. after 6 hours' rest	–	–	2,610	–
2 August	Measured bed B. after 17 hours' rest. Heavy rain previously.	–	3,220	–	–
	Remeasured after 1¼ hours' draining	–	2,980	–	–
3 ,,	Measured bed A. after 6 hours' draining	2,170	–	–	–
9 ,,	Measured bed B. after 7 days' rest. Wet weather	–	3,540	–	–
	Remeasured after 1¼ hours' draining; rain in meantime	–	3,110	–	–
17 ,,	Bed C. raked over.	–	–	–	–
23 ,,	Measured bed C. after week's rest	–	–	3,100	–
24 ,,	Measured bed C. after 6 hours' rest	–	–	2,740	–
	Bed A. raked over.	–	–	–	–
30 ,,	Measured bed A. after 7 days' rest	2,950	–	–	–
31 ,,	Measured bed A. after 6 hours' rest	2,450	–	–	–
	From this date bed D. held full only until upper bed is empty, then slowly emptied and sampled every ¼ hour.				
6 September	Measured bed B. after 7 days' rest	–	3,680	–	–
	Remeasured after 1¼ hours' rest	–	3,050	–	–
8 ,,	Beds A., C. and D. rested after this date.	–	–	–	–
10 ,,	Bed D. measured after 1 day's rest	–	–	–	2,220
	Remeasured after 2½ hours' draining	–	–	–	1,880
11 ,,	Measured bed C. after 2 days' rest	–	–	2,940	–
17 ,,	Measured bed D. after 8 days' rest	–	–	–	2,530
	Measured bed A. after 8 days' rest	3,060	–	–	–
18 ,,	Measured bed C. after 9 days' rest	–	–	3,200	–
24 ,,	Measured bed D after 15 days' rest	–	–	–	2,570
	Remeasured bed D. after 2½ hours' draining. Wet weather.	–	–	–	2,130
27 ,,	Beds A., C. and D. commenced working. Measured bed A. after 6 hours' draining.	2,660	–	–	–
28 ,,	Measured bed C. after 6 hours' drainage	–	–	2,740	–
4 October	Measured bed B. after 7 days' rest. Very wet weather	–	3,520	–	–
	Remeasured after 1½ hours' draining	–	2 810	–	–
15 ,,	Measured bed A. after 6 hours' draining. Wet weather	2,330	–	–	–
	Remeasured after 2 hours' draining	2,270	–	–	–
16 ,,	Measured bed A. after 4 hours' draining	2,200	–	–	–
	Remeasured after 2 hours' draining	2,050	–	–	–
25 ,,	Measured bed A. after 7 days' rest. Very wet	2,690	–	–	–
26 ,,	Measured bed A. after 6 hours' draining. Wet	2,430	–	–	
31 ,,	Measured bed B. after 1½ hours' draining	–	2,680	–	

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Record of Working of Bacteria Beds—*continued.*

Date.	Remarks.	Capacity in Gallons.			
		A.	B.	C.	D.
1900:					
1 November	Measured bed C. after 6 hours' draining	–	–	2,610	–
8 „	Measured bed B. after 7 days' rest	–	3,310	–	–
	Remeasured bed B. after 1¼ hours' drainage	–	2,780	–	–
9 „	Measured bed C. after 6 days' rest	–	–	3,130	–
10 „	Measured bed A. after 7 days' rest	2,830	–	–	–
12 „	Removed shoots from bed C.	–	–	–	–
13 „	Removed shoots from bed A.	–	–	–	–
	Grips cut on A. and C., as on B.				
28 „	Extra filling put on A. during storm flow. C. and A. filtrates, both run on to D. simultaneously.	–	–	–	–
6 December	Extra filling put on C. at 1 p.m.	–	–	–	–
	Bed A. resting 1 week from this date.	–	–	–	–
20 „	Bed B. resting 1 week from this date.	–	–	–	–
22 „	Bed D. raked.	–	–	–	–
1901:					
2 January	Measured bed A. after 6 hours' draining	2,020	–	–	–
5 ,	Bed A. raked.	–	–	–	–
10 „	Measured bed A. after 7 days' rest	2,540	–	–	–
11 „	Measured bed A. after 6 hours' draining; rain in the meantime.	2,060	–	–	–
17 „	Measured bed C. after 7 days' rest	–	–	2,850	–
19 „	Measured bed C. after 6 hours' draining	–	–	2,230	–
24 „	Measured bed B. after 7 days' rest	–	3,110	–	–
	Remeasured bed B. after 1½ hours' draining. Filled a little above mark.	–	2,780	–	–
31 „	Measured bed A. after 6 hours' draining	1,800	–	–	–
5 February	Measured bed D. after 2½ hours' draining. Snow on surface of the bed.	–	–	–	1,79[illegible]
7 „	Measured bed A. after 7 days' rest. Snow on surface of bed almost all week.	2,410	–	–	–
8 „	Measured bed A. after 6 hours' rest	1,910	–	–	–

FILTRATION OF OPEN SEPTIC TANK EFFLUENT ON BEDS A., C., AND D.—MANCHESTER.

Date. Week Ending	Quarter ending 26th September 1900.																						Incubator Test.								
																							3 Minutes—Oxygen Absorption.							Putrescibility.		
	Oxygen Absorbed—4 Hours.				Free and Saline Ammonia.				Albuminoid Ammonia.				Chlorine.				Nitrites.			Ammonia from Nitrites and Nitrates.			Before Incubator.				After Incubator.					
	Tank Effluent.	Bed A.	Bed C.	Bed D.	Tank Effluent.	Bed A.	Bed C.	Bed D.	Tank Effluent.	Bed A.	Bed C.	Bed D.	Tank Effluent.	Bed A.	Bed C.	Bed D.	Bed A.	Bed C.	Bed D.	Bed A.	Bed C.	Bed D.	Tank Effluent.	Bed A.	Bed C.	Bed D.	Bed A.	Bed C.	Bed D.	Bed A.	Bed C.	Bed D.
4 July	6·48	–	1·45	·50	2·00	–	·64	·146	·300	–	·130	·040	12·3	–	11·0	10·8	–	·028	·017	–	·58	1·11	3·61	–	·76	·20	–	·70	·19	–		
11 "	6·07	–	1·44	·56	2·05	–	·62	·160	·295	–	·130	·046	12·3	–	11·9	11·6	–	·012	·016	–	·35	·94	3·39	–	·81	·23	–	·77	·18	–		
11 "	5·96	1·64	–	·59	2·16	·62	–	·152	·310	·160	–	·050	12·3	11·3	–	11·0	·025	–	·021	·37	–	·84	3·37	·90	–	·24	·84	–	·18	–		
18 "	5·85	2·05	–	·60	2·47	·88	–	·240	·300	·140	–	·057	13·0	12·4	–	11·8	·004	–	·027	·11	–	·64	3·09	1·10	–	·25	1·56	–	·21	–		
18 "	6·04	–	1·71	·56	2·47	–	·79	·246	·300	–	·130	·052	12·9	–	12·4	11·7	–	·017	·021	–	·12	·66	3·32	–	·96	·26	–	1·32	·21	–		
25 "	7·02	2·50	–	·68	2·70	1·00	–	·310	·385	·174	–	·078	13·2	12·7	–	12·3	·002	–	·025	·05	–	·71	3·97	1·32	–	·29	1·76	–	·24	–		
1 August	6·19	–	1·41	·57	2·47	–	·62	·160	·360	–	·060	·071	12·1	–	11·9	11·4	–	·023	·019	–	·43	·92	3·56	–	·71	·22	–	·69	·19	–		
8 "	3·86	1·09	·89	·41	1·59	·49	·41	·075	·270	·120	·105	·042	7·6	7·6	7·6	7·4	·044	·040	·022	·65	·34	·89	1·81	·48	·37	·16	·39	·36	·13			
15 "	4·92	1·65	1·35	·48	2·25	·64	·58	·142	·320	·130	·127	·040	11·0	9·6	10·4	9·9	·035	·020	·018	·15	·19	·78	2·54	·78	·61	·23	·84	·62	·13			
22 "	5·37	1·84	–	·48	2·50	·77	–	·180	·320	·145	–	·050	12·2	12·0	–	12·0	·017	–	·020	·10	–	·79	3·40	1·09	–	·22	1·33	–	·18	–		
29 "	5·78	–	1·36	·47	2·39	–	·63	·190	·380	–	·130	·064	13·0	–	11·6	10·9	–	·021	·022	–	·63	·85	3·23	–	·72	·21	–	·71	·18	–		
5 September	6·38	1·86	1·80	·64	2·89	·94	·97	·321	·410	·163	·176	·080	13·0	12·8	13·5	13·1	·070	·041	·030	·26	·16	·66	3·62	1·01	·94	·27	1·12	1·07	·21			
12 "	7·67	2·33	2·22	·73	3·12	·85	·97	·320	·420	·150	·150	·070	15·4	14·1	14·0	13·0	·040	·022	·025	·05	·05	·75	3·18	1·24	1·14	·29	1·43	1·41	·23			
19 "	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
26 "	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Average	5·97	1·87	1·51	·56	2·39	·78	·69	·19	·34	·148	·137	·057	12·4	11·6	11·6	11·3	·030	·025	·022	·218	·317	·810	3·24	·99	·78	·24	1·16	·85	·19			

Quarter ending 26th December 1900.

3 October	6·15	1·68	1·45	·64	2·07	·59	·60	·225	·360	·162	·170	·077	12·7	11·1	10·8	10·5	·037	·030	·030	·755	·660	1·120	3·36	·90	·76	·290	·66	·54	·23			
10 "	5·57	1·33	1·21	·54	1·55	·48	·39	·125	·305	·110	·102	·047	10·4	10·2	10·1	10·0	·033	·021	·026	·370	·455	·680	2·94	·62	·55	·230	·62	·39	·17			
17 "	6·40	1·56	1·38	·51	2·06	·59	·47	·160	·365	·140	·120	·044	12·2	10·6	11·3	10·8	·025	·017	·025	·410	·500	·800	3·21	·71	·62	·235	·58	·45	·18			
24 "	7·24	–	1·60	·61	2·19	–	·62	·212	·370	–	·140	·061	14·1	–	13·3	12·9	–	·024	·037	–	·555	·810	3·63	–	·73	·260	–	·59	·18	–		
31 "	5·18	1·20	–	·52	1·54	·37	–	·080	·310	·120	–	·042	9·0	8·1	–	8·0	·030	–	·024	·810	–	·950	2·68	·56	–	·220	·40	–	·17			
7 November	5·55	1·11	1·02	·50	1·85	·53	·40	·175	·315	·155	·125	·053	10·1	10·0	9·7	9·2	·015	·014	·015	·560	1·000	·910	2·87	·54	·55	·210	·34	·30	·15			
14 "	4·35	1·26	1·12	·52	2·58	·68	·77	·320	·370	·140	·120	·068	8·5	7·6	7·6	7·6	·015	·012	·013	1·260	1·450	1·810	2·45	·53	·51	·240	·35	·28	·15			
21 "	6·11	1·68	1·43	·61	2·37	·72	·67	·340	·390	·160	·140	·090	11·6	10·9	10·9	10·5	·018	·012	·022	·800	·930	1·140	3·10	·81	·70	·270	·55	·44	·21			
28 "	6·87	1·87	1·59	·58	2·44	·79	·82	·370	·400	·170	·160	·060	13·3	12·8	12·6	12·4	·020	·017	·023	·550	·670	·890	3·71	1·01	·84	·280	·77	·57	·17			
5 December	6·30	1·72	1·50	·48	1·77	·78	·75	·280	·375	·146	·140	·061	11·3	11·3	11·3	11·1	·030	·036	·034	·590	·690	·950	3·19	·88	·78	·210	·75	·67	·17			
12 "	6·65	–	1·46	·40	1·72	–	·48	·174	·390	–	·130	·043	11·6	–	10·2	9·7	–	·030	·018	–	·580	·910	3·45	–	·73	·140	–	·71	·09	–		
19 "	6·65	1·61	–	·51	2·11	·82	–	·254	·370	·160	–	·061	12·0	11·3	–	11·1	·037	–	·032	·620	–	·910	3·44	·86	–	·230	·76	–	·17			
26 "	6·47	1·58	1·32	·47	2·16	·80	·78	·215	·340	·140	·130	·050	11·2	10·9	10·7	10·8	·018	·014	·024	·460	·670	·780	3·32	·79	·68	·190	·66	·48	·16			
Average	6·11	1·51	1·37	·53	2·03	·65	·61	·225	·36	·146	·134	·057	11·4	10·4	10·8	10·4	·025	0·21	·025	·653	·740	·970	3·18	·71	·68	·227	·59	·49	·17			

Results given in Grains per Gallon.

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APPENDIX II.—*continued.*

FILTRATION OF OPEN SEPTIC TANK EFFLUENT ON BED B.

Date.	Quarter ending 26th September 1900.										Incubator Test.			
											3 Minutes—Oxygen Absorption.			
	Oxygen Absorbed—4 Hours.		Free and Saline Ammonia.		Albuminoid Ammonia.		Chlorine.		Nitrites.	Ammonia from Nitrites and Nitrates.	Before Incubator.		After Incubator.	Putrescibility.
Week ending.	Tank Effluent.	Bed B.	Tank Effluent.	Bed B.	Tank Effluent.	Bed B.	Tank Effluent.	Bed B.	Bed B.	Bed B.	Tank Effluent.	Bed B.	Bed B.	Bed B.
4 July	5·58	1·94	1·97	·87	·300	·150	11·8	11·3	·020	·22	3·20	1·07	1·20	1/3
11 „	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18 „	5·09	1·95	2·40	1·20	·290	·200	12·4	10·9	·060	·28	2·79	1·05	1·10	1/5
25 „	6·86	2·79	2·66	1·33	·355	·187	12·5	12·2	Nil	·05	3·92	1·55	1·86	1/3
1 August	5·37	1·70	2·23	·92	320	·139	10·6	10·3	·012	·06	3·01	·97	1·10	3/4
8 „	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15 „	4·37	1·71	1·73	1·00	·280	·153	10·6	9·9	·041	·29	2·72	·83	·68	1/2
22 „	5·72	1·92	2·18	·96	·340	·170	11·7	11·3	·044	·16	3·22	1·02	·96	1/2
29 „	5·44	1·65	2·47	·92	·330	·136	12·1	11·5	·035	·39	3·21	·90	·91	2/3
5 September	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12 „	7·30	2·20	3·00	1·26	·400	·167	14·4	13·0	·053	·51	3·77	1·14	1·16	2/3
19 „	6·67	2·10	2·39	1·23	·370	·170	13·4	13·0	·065	·42	3·87	1·26	1·06	1
16 „	7·49	2·16	2·62	1·09	·360	·170	13·4	13·8	·050	·42	4·04	1·07	·98	1/2
Average	5·99	2·01	2.36	1·08	·330	·160	12·3	11·7	·038	·28	3·37	1·09	1·10	11/14

Results given in grains per gallon.

APPENDIX II.—*continued.*

FILTRATION of Open Septic Tank Effluent on Bed B—*continued.*

DATE.	QUARTER ENDING 26TH DECEMBER 1900.										INCUBATOR TEST.			
											3 Minutes—Oxygen Absorption.			Putrescibility.
	Oxygen Absorbed—4 Hours.		Free and Saline Ammonia.		Albuminoid Ammonia.		Chlorine.		Nitrites.	Ammonia from Nitrites and Nitrates.	Before Incubator.		After Incubator.	
Week ending—	Tank Effluent.	Bed B.	Tank Effluent.	Bed B.	Tank Effluent.	Bed B.	Tank Effluent.	Bed B.	Bed B.	Bed B.	Tank Effluent.	Bed B.	Bed B.	Bed B.
3 October	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10 „	4·81	1·22	1·58	·65	·29	·11	9·9	9·1	·037	·74	2·68	·58	·34	1/2
17 „	5·84	1·35	2·02	·82	·32	·15	11·8	11·1	·015	·57	2·96	·66	·51	1/2
24 „	6·45	1·72	2·18	·88	·35	·17	13·5	13·0	·024	·55	3·34	·80	·56	1/2
31 „	4·93	1·21	1·42	·59	·28	·12	8·7	8·5	·019	·52	2·55	·56	·39	1/2
7 November	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14 „	3·89	1·15	2·20	1·05	·35	·16	8·4	7·2	·005	1·23	2·20	·56	·29	1/2
21 „	5·54	1·62	2·21	1·01	·37	·18	11·3	10·8	·014	·74	2·98	·83	·50	1/2
28 „	6·16	1·81	2·08	1·02	·37	·17	12·7	12·3	·016	·57	3·66	·99	·63	1/2
5 December	5·88	1·51	1·91	·80	·35	·17	11·3	11·1	·030	·58	3·23	·80	·56	1/2
12 ,	5·29	1·16	1·52	·65	·35	·14	10·4	9·7	·026	·47	2·99	·60	·38	1/2
19 „	6·32	1·55	1·78	·93	·35	·15	11·6	11·1	·015	·52	3·32	·81	·62	1/2
* 26 ,	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Average	5·51	1·43	1·89	·84	·33	·15	11 0	10·4	·020	·65	2·99	·72	·48	1/10

Results given in grains per gallon.

TREATMENT OF SEWAGE IN CLOSED SEPTIC TANK AND CONTACT BEDS, MANCHESTER.

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Removal of Sludge from Septic Tank.

After 20 months working the flow of sewage through the tank was stopped, and the contents pumped out. After removing the water, a stratum of sludge about 3¼ feet in depth was left; this was pumped out as far as possible by means of a chain pump. A residue which could not be reached by the pump was left in, averaging in depth about 3¼ inches.

Allowing for this residue, the total sludge in the tank was estimated at 65 tons, the sludge removed contained 88·7 per cent. moisture.

During the period of work the toal flow of sewage through the tank was estimated at 14,400,000 gallons.

Allowing 26·0 grains per gallon suspended matter in the sewage 240 tons of sludge containing 90 per cent. moisture would normally be produced. From the above results it might be calculated that not more than 30 per cent. of the total sludge requires to be dealt with in the tank.

It must, however, be borne in mind that a large amount of suspended matter has found its way on to the surface of the beds, causing the level of these to rise.

It is questionable also whether the sewage arriving at the septic tank contained quite its full proportion of suspended matter.

Working of Contact Beds.

During the past year the beds have been filled regularly as far as possible by the automatic apparatus, each bed receiving 12 fillings during the week from Monday, 6 a.m., to Saturday noon.

The average composition of the filtrates obtained from January 24th to December 26th, 1900, was as follows:—

	Parts per 100,000.		Parts per 100,000.
Oxygen absorption—		Ammoniacal Nitrogen	1·02
4 Hours' test	1·93	Albuminoid „	0·12
3 Minutes before incubator	1·03	Nitrous „	0·043
3 „ after „	·66	Nitric „	0·80
Putrescibility	8½—404	Chlorine	15·4

Measurements of capacity have been as follows:—

Date.	Capacity in Gallons.	Remarks.
19 June 1900	2,000	After 8 hours' rest.
23 January 1901	2,200	„ 10 „ „
13 February	2,200	„ 8½ „ „

Taking the capacity of the beds at 2,000 gallons, this gives at two fillings per day, 592,000 gallons per acre per day, without allowing for Sunday's rest.

General Observations.

First Flush and Drainings.

While the first flush from the beds was turbid and often putrefactive its effect was not considered serious, as it did not last more than a few minutes, the drainings from the bed after emptying attain a high degree of purity, and when these are mixed with an equal volume of the first flush, the mixture is in general non-putrefactive.

Maintenance of Beds.

The surfaces of the beds have been periodically raked and occasionally forked up to a depth of about 6 inches. In process of time the surface has risen above the level of the distributing channels to an extent of about 6 inches, the material having the general character of garden soil, which finally tends to impede the filling of the bed. If, however, this upper layer be removed the clinker below is fairly loose.

In one or two cases the upper layer has been removed, and on again putting the bed into use it takes the water freely, and in process of time the layer is reformed.

Working of Automatic Gear.

When all the working parts are in good condition, the apparatus is capable of working smoothly and well. The corrosive action of the septic tank effluent tends, however, to loosen any screws or nuts exposed to it, and the connecting pipes also become in time coated with deposit, so that frequent attention is necessary from these causes.

One difficulty with apparatus depending for its action on the rate of flow of sewage is that the cycle must vary with the flow, and is shortest when this is at its height, an increased flow, however, in dry weather, coincides with the strongest sewage, and therefore some method of ponding up would have to be resorted to in this case. In the experiment as carried out, the flow was kept fairly constant throughout the day. It was noticed that when a bed is tight, water will not penetrate fast enough to enable the flow to be diverted from the bed before considerable ponding has taken place on the surface.

An inherent difficulty with automatic gear depending on the sewage flow is that the cycle of one bed is dependent on the condition, capacity, character of surface, etc., of another bed, which will vary according to circumstances, length of working, weather, etc.

The Stoddart Patent Continuous Filter.

An experiment with this filter was begun on August 8th, 1900, and continues at the present time. The filter is rectangular having a surface area of 16 square yards, and a depth of 6 feet. The material consists chiefly of large clinkers, the top foot being of coke, the dimensions of both being 3 inches by 2 inches. The filter was placed about midway on the east side of the open septic tank, and received effluent from this tank by means of a junction with a pipe supplying the other experimental filters.

The material was placed upon a dished concrete floor, and kept in position by a framework of boarding, spaces of about an inch being left between the boards. The filter being constructed near a bank, some excavation was necessary, and the base of the filter was surrounded by earth to a depth varying roughly from one to two feet. This was afterwards cut completely away on two sides, but the filtrate could at all times flow freely away through two 2-inch pipes into a manhole.

The tank effluent was distributed upon the surface of the material by means of Stoddart's patent distributor. The tank effluent flows into a supply channel of cast iron, and thence along perforated gutters of corrugated zincs, the perforations are cut in diamond shape at in-

tervals along the upper edges of the corrugations, through the lower edges small holes are made which admit ordinary nails, the latter serving as points from which the liquid can flow. The tank effluent flows through the diamond shaped perforations of the distributors, and falls from the ends of the nails in a series of drops.

The average rate of flow through the filter up to December 26th, 1900, was 240 gallons per square yard per day, this has since been increased to about 350 gallons per square yard, and the filtrate is of fair quality.

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During the earlier period of working large quantities of suspended matter came away with the filtrate, and this is still the case to a great extent.

The average analytical numbers up to December 26th, 1900, are as follows, both shaken and settled samples being analysed.

	Parts per 100,000.			Parts per 100,000.	
	Shaken.	Settled.		Shaken.	Settled.
Oxygen absorption—			Ammoniacal Nitrogen - -	2·02	1·97
4 Hours' test - - -	2·96	2·43	Albuminoid „ - -	·234	·195
3 Minutes before incubator -	1·74	1·43	Nitrous „ - -	·084	–
3 „ after „ -	1·67	1·26	Nitric „ - -	·221	–
Putrescibility - - - -	50·7%	23·4%	Chlorine - - - - -	15·7	–

Considerable difficulty was experienced in getting the corrugated zinc sheets properly level in order to ensure equal distribution. Any difference in level is, of course, more noticeable when the flow is small, with an increased flow it is scarcely apparent. After the filter had been working some time it was found that a considerable amount of leakage took place at the junction of the distributing channel with the shoots. This was found to be due in some degree to the partial disintegration of the felt used in making the joint. A considerable amount of sludge accumulates in the distributing channel and shoots, in a comparatively short period of time. This has to be periodically removed, during which operation it is almost impossible to prevent a certain amount of it from finding its way on to the filter.

A filter of this kind appears to be unsuited to deal with an effluent containing so much suspended matter as the open septic tank effluent in Manchester, further settlement either before or after filtration will certainly be required. It is probable that better results would be obtained with a tank effluent possessing a low oxygen absorption and a high albuminoid ammonia value. It appears as if, in the case of Manchester sewage, the oxidising power of the filter is exercised largely on matters other than sewage, so that nitrification is to that extent impeded. The cost of construction of this filter is found to be considerable, and a high rate of working must be attained if it is to be economical. It is possible that the distributor might find useful application in reducing the necessary area of second contact beds, as a large quantity of the effluent from first contact beds could doubtless be dealt with per square yard of such a filter.

GENERAL CONCLUSIONS REGARDING THE MAINTENANCE AND WORKING OF CONTACT BEDS, MANCHESTER.

From the general experience gained from the working of the various experimental installations, the following conclusions have been arrived at:—

I. Construction of Beds.

The beds should be so constructed as to admit of—

(a) Rapid drainage.

(b) Retention of suspended matter as far as possible near the surface.

(c) Limited number of inlet and exit valves.

(a) The half-acre beds proposed to be used on the large scale will be under-drained radially by means of channels in the concrete bottom, the invert of these channels will slope towards a semi-circular collecting channel communicating with the discharge well. The radiating channels will be covered with perforated tiles, and those with rough clinker to a depth of about one foot.

The discharge valve is of sufficient size to empty the bed in half an hour, the outward rush of the water into the pick-up channel being moderated by distribution through a series of further small openings.

(b) The surface of the clinker will be covered to a depth of a few inches by the screenings from the main bulk of clinker which have passed through a 3-8th inch mesh, the main body of the bed being composed of clinker from about 1½″ to 3-8″ in size. In practice the most economical method of preparing the material appears to be to remove the heavier clinkers which naturally fall to base of the tip, and use them for covering the drains, the remainder is screened through a 3-8″ screen, driven by mechanical power, the screenings are utilised as above described, or used instead of sand, in the making of concrete.

The tank effluent is admitted on to the filter over a semi-circular cill, so that it spreads in a thin sheet over the surface of the cinders; if necessary grips may be cut in the surface of the cinders for better distribution.

In this way it is hoped that the greater part of the suspended matter will be arrested near the distributing cill.

(c) The method of emptying the bed by means of a single penstock has already been described. Two penstocks only will be needed to admit the tank effluent into the shallow distributing reservoir, bounded by the semi-circular cill above mentioned.

II. Control of Beds.

An apparatus has been devised, by which it is hoped that the inlet sluices may be actuated from a central switch room, by means of electric motors. The water once admitted to the bed the various operations necessary to complete the cycle will be performed automatically. In this way it will be possible to exercise control over the filling of the beds, and thus regulate the working of a bed according to its condition.

(The above details of construction have been worked out by J. P. Wilkinson, C.E., the engineer appointed by the Rivers Committee.)

III. Maintenance of Beds.

Initial Period of Working.

Care will be taken at the commencement of working to put no more work on the bed than it is capable of performing, as it is difficult to thoroughly recover a bed if it has once been over-worked.

For example, two fillings a day should not be exceeded until good nitrification has been obtained.

Resting Periods.

Experiment has shown that purification effected depends rather upon the amount of effluent dealt with per given area, than upon the length of cycle employed.

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Two short cycles and one long one in the 24 hours give results equal to, if not better than, three cycles of equal duration. Variations in the rate of flow can thus be dealt with, and in cases of large increase of flow the rate of working of the beds may be temporarily increased without subsequent ill effects. It appears that the period of rest is of more consequence than the period of contact, and that in most cases it is not advantageous for the latter to exceed one hour.

The choice of lengthened periods of rest will be conditioned by (i) the state of the bed, (ii) the weather and (iii) the season of the year, *e.g.*,

(i) If a bed is working well, and its capacity appears to be maintaining itself, it would not be economical to interrupt its activity.

(ii) If possible, necessary rests should be given when the weather is fine, dry and breezy.

(iii) It will not be advisable to rest the beds for a lengthened period in very cold weather, as in the absence of the heat of the sewage, the bacterial activity is to a large extent inhibited. If it is necessary to rest under these conditions it should be done by reducing the number of fillings per day.

Judgment will be required to be exercised in all cases in considering the simultaneous effect of variations in the above conditions. Other things being equal it appears preferable to allow a bed a period of complete rest rather than simply to reduce the number of fillings, as it has been found after a rest of, say, a week, that nitrification continues exceptionally active for about ten days.

On the other hand, the extension of resting period beyond a certain length is unaccompanied by any increase in capacity or other good result.

Work upon surface of Bed.

At no time should the surface of a bed be allowed to become water-logged. If such a tendency manifests itself the bed should be rested, and the surface raked to not more than the depth of the upper layer. If raking is not adequate for the purpose it may be necessary to remove some of the top layer and pile it in heaps, possibly on the bed itself, for an indefinite length of time, to recover. This may be eventually put back in place of further clogged material.

Washing of Material.

In addition to the work on the surface of the beds above mentioned, it may be necessary at very infrequent intervals, to wash a portion at least of the main bulk of the material. Experiment has shown that it will not be economical to wash the surface layer, but the larger clinkers below should be capable of being rapidly and cheaply washed in a specially devised machine. The slurry may be allowed to run off along specially constructed channels to the surface of one of the storm beds, where it can be allowed to dry, and afterwards spaded off. It has been found that such slurry, or washed out material, is perfectly inoffensive and dries down to a substance having the character of garden mould.

IV. Treatment of Storm Water.

Twenty-five acres of roughly constructed beds will be provided for the treatment of the storm water of Manchester. Experience with a similar bed had shown that with one or two fillings per day of settled sewage good results may be obtained in dry weather; under such conditions these beds may be used to relieve to some extent the work on the ordinary beds, while at the same time they are kept in an active condition, ready to receive much larger quantities of storm water up to the maximum necessary to be treated.

It is important that these beds should not receive any but fresh sewage, and consequently only sewage which has passed through special sedimentation tanks will be allowed to reach them. There will be four of these special tanks provided, two of which should be kept empty to receive a portion of the first flush of storm water.

The facts which have led to the belief that contact beds can be worked for a long period without the occurrence of serious clogging in the main body of the bed may be summarised as follows:—

1. The Roscoe beds have dealt with tank effluent from chemical precipitation with lime and copperas at a rate, including all rests, of upwards of 500,000 gallons per acre per day for five years.

After a preliminary loss the capacity remained practically constant for several years, and was still 1,000 gallons at the end of five years, the initial measurement being 1,750 gallons.

2. The examination of the material of the Roscoe beds showed that fine suspended matter had not penetrated to any great extent below the upper foot, this coinciding with the depth to which the beds have been disturbed by forking.

It is probable that if this operation had not been carried so far the beds would not have been affected to so great a depth.

3. The surface of the beds in course of time rose several inches above their original level.

4. A bed consisting for the most part of fine cinder screenings has received tank effluent from chemical precipitation for nine months without showing any sign of clogging below the first few inches.

5. A bed 1·7 acre in extent roughly constructed of unscreened clinkers has received tank effluent and storm water for 18 months, without clogging being apparent anywhere except immediately in the vicinity of the inlet valve.

6. Beds which have received effluent from a closed septic tank for two years have been found to acquire a practically constant capacity, and the surface has piled in a similar manner to the Roscoe filters.

7. Beds receiving effluent from the open septic tank for the last 12 months have on the whole not seriously lost capacity, such losses as occurred being to a large extent recoverable by rest.

8. Beds at Friern Barnet (near London), Clifton Junction (near Bolton) which have a layer of fine material on the top have remained in action satisfactorily for upwards of 10 years. A sample of clinker taken below the upper layer from the bed at Clifton Junction after about 10 years was found to be quite clean and sharp.

9. Similar results have been obtained at Oldham, and are confirmed in the 1899 report of the Massachusetts Board of Health. (Filtration of Septic Effluent.)

THIRTY-FIRST DAY.

Tuesday, May 7th, 1901.

PRESENT:

The Right Hon. The Earl of IDDESLEIGH (*Chairman*) *presiding.*

Mr. THOMAS WILLIAM KILLICK.
Mr. WILLIAM HENRY POWER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Mr. CHARLES PHILIP COTTON.
Major-General CONSTANTINE PHIPPS CAREY, R.E.

Mr. F. J. WILLIS, *Secretary.*

PRESENT ALSO:

Dr. G. McGOWAN. | Dr. A. C. HOUSTON.

Professor E. A. LETTS, D.Sc., Ph.D., called; and Examined.

Professor E. A. Letts, D.Sc., PH.D. — 7 May 1901.

8573. (*Chairman.*) I think that you are Dr. Letts, Professor of Chemistry at Queen's College, Belfast?—I am.

8573*. You have had some experience of where sewage or sewage effluents come into tidal water?—Yes.

8574. Perhaps you would not mind giving us a general statement containing such information as you can give us?—Yes, my Lord. First of all, the evidence which I propose to give here is on the matter of a peculiar seaweed which occurs in Belfast Lough, and gives rise to a very serious nuisance there; and, secondly, I propose to say something about experiments which I have made on the changes which occur in mixtures of sewage and seawater, so with your permission I will take those two branches separately. As regards the first point, that is the occurrence of this seaweed in Belfast Lough, for a number of years past a most serious nuisance has arisen in the Lough during the summer and the autumn. The stench, especially at low tide from the foreshore of the Lough, being quite overwhelming, and the air very heavily charged with sulphuretted hydrogen. A precisely similar nuisance, though not of the same magnitude, arises from the foreshore in the northern portion of Dublin Harbour, which I also am very well acquainted with, as I have to be there two or three times a year. Now, the nuisance in Belfast at all events has been supposed by a great many people to be due to sewage matters actually deposited upon the slobland, because the sewage of the town runs directly into the Lough; formerly it ran into the river. But it requires very little observation to show that that is not the true explanation at all. The nuisance invariably is associated with deposits of this filmy green seaweed, which is called *Ulva Latissima*, or sea lettuce. I have brought here specimens of this weed to show the Commission. (*Specimens exhibited.*) I may mention here that others have noticed the occurrence of this seaweed in polluted sea water, and the nuisance which may arise from it; indeed, during the investigations which we have been making on this subject I received a letter from Professor Hartley to this effect, that "the seaweed is never seen on any shore unless sewage runs into the water. The stronger the sewage and the greater its volume, the more luxuriant is its growth. I have observed this," he says, "during the last twenty years in England, Wales, Ireland, and Scotland. About eight years ago I washed some of the weed in fresh water, and placed it in a bottle of the same. In about twenty-four hours the bottle was opened, and the contents found to be in an exceedingly offensive state. A paper of mine in the Proc. Roy. Soc., Edinburgh, session 1895-96, touches upon this matter." In point of fact that paper of Professor Hartley's does not touch upon the seaweed but upon ocean deposits, and especially the occurrence of sulphates and sulphuretted hydrogen. I may mention that when I read our paper before the British Association on the subject, the botanists there seemed to be of opinion that this seaweed was more characteristic of brackish water than of polluted water, and they were rather surprised at what I said about its luxuriance in polluted water. In the upper reaches of Belfast Lough this seaweed grows in almost incredible quantities, and during high winds or gales it is washed ashore, forming banks which are frequently three or four feet thick, and extend for miles along the coast, especially on the southern side of Belfast Lough. In the northern portions the quantity of seaweed, for some reason or other—the exact reason I am not so sure of—is not so large as in the southern portions of the Lough. When the seaweed is once deposited, the layers of it often remain more or less stationary in the shallow bays or pools in the neighbourhood for months, and under those circumstances, and particularly in warm weather, rapid putrefaction occurs, and a perfectly intolerable stench arises, which is perceptible over a wide area, and seriously affects not only the comfort of the inhabitants of the district, but the value of their property also; and in my opinion their health in addition. Here is some of this seaweed which was allowed to ferment in a bottle of sea water for some time. It will give you some idea of the character of the nuisance. I am afraid you will smell it without the stopper being removed at all. That is merely the pure weed. It has been well washed with water, and put into sea water. (*Sample produced.*) Perhaps I may be allowed to give an instance of how great the quantities are which grow in Belfast Lough. There is one small bay close to where I live—I live on the shore of the Lough myself—I should say about a quarter of a mile across which was covered with this weed in the year 1899, and I asked the harbour engineer, who is a neighbour of mine, if he would give me some idea of the quantity in that small bay. "Well," he said, "I should judge that the quantity there is over 1,000 tons," and that was only one small bay. As regards the evolution of sulphuretted hydrogen sometimes—it is perfectly incredible the quantities which are evolved from the decaying weed. The Belfast Guardians paid us a visit in the year 1889. I had never tried the experiment before, but I took them down to the shore and brought a piece of lead paper with me, and simply exposed it to the air, and it darkened just as rapidly as a piece of photographic printing paper. I had never seen anything like it even from a very foul sewer; in fact, the Guardians, who were very suspicious gentlemen, said "it is a piece of photographic paper blackening under the influence of the light; not sulphuretted hydrogen." The smell very often reaches a distance from half a mile to a mile inland, so that will give you some idea of the extent of the nuisance. Then as regards the matter of health, I cannot find that the medical men will allow that it is actually injurious to health. They are a little bit cautious about it, and they take rather the death rate as indicating what is injurious to health and not other things. Now, I think that a number of things can be injurious to health without affecting the death rate in the very slightest degree, and some instances of what I would call affecting health have occurred to my knowledge. For instance, I was once walking with a lady by some of these decaying masses, and after we had passed them she simply collapsed, and became as white as a sheet; evidently it had affected her in that way. And then again I have known people arriving fresh from a different locality in this place, and presently they would be seized with bad headache and vomiting, which they attributed themselves to the smell, and indeed headaches and loss of appetite are very common down there with many of the people who are not very strong, so that I think, although it may not affect the death rate, it does affect the health of the people during the months when it is worst.

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The nuisance became so bad in the year 1898 to 1899 that the patience of the inhabitants of the district became wellnigh exhausted. An influential committee was formed of the residents on both sides of Belfast Lough, and a deputation waited upon the Lord Mayor and the City Council, and eventually the City authorities undertook to introduce a scheme of sewage purification within three years from the year 1899. Meanwhile I was engaged with my pupil, Mr. J. Hawthorne, B.A., in an investigation, the original object of which was merely to ascertain the cause of the Belfast nuisance. We were gradually led into a more extended inquiry, which has embraced not only a study of the chemical changes which occur when *Ulva latissima* ferments, but in addition an examination of the composition and character of the seaweed, the isolation of the products of its fermentation, attempts to isolate the particular micro-organisms giving rise to those products, and lastly, we have endeavoured to ascertain both experimentally and by an examination of localities in Ireland in which the weed is either present in quantity or is virtually absent, the relationship of *Ulva latissima* to the pollution of sea water by sewage.

(*Reprinted from the Proceedings of the Royal Society of Edinburgh.*)

The seaweed *Ulva latissima* and its relation to the pollution of Sea Water by Sewage.

By Professor Letts and John Hawthorne, B.A., Queen's College, Belfast.

(With plates.)

(Read March 4, 1901.)

For a number of years a very serious nuisance has arisen from the "sloblands" of the upper reaches of Belfast Lough during the summer and early autumn —the stench at low tide being often quite overpowering and the air heavily charged with sulphuretted hydrogen.

A precisely similar nuisance, though not of the same magnitude, arises from the sloblands in the northern portion of Dublin harbour.

This nuisance, in Belfast, at all events, has been supposed by many people to be due to sewage matters actually deposited on the slobland, but it requires but slight observation to prove that this can scarcely be the true explanation, for without doubt the nuisance is intimately associated with deposits of green seaweed, consisting almost entirely of the *Ulva latissima*, or, as it is commonly called, the "Sea Lettuce."*

In the upper reaches of Belfast Lough this weed grows in abundance, and during high winds or gales it is washed ashore, often in enormous quantities, forming banks which are frequently two or three feet thick, and extend at times for miles along the coast, especially on the southern shore.

Once deposited, these layers of weed often remain more or less stationary in the shallow bays or pools of the neighbourhood for months, and under these circumstances, and particularly in warm weather, rapid putrefaction occurs, and a perfectly intolerable stench arises, which is perceptible over a wide area, and seriously affects, not only the comfort of the inhabitants of the district, but the value of their property also.

. . . . . .

The investigation, the results of which we describe in the following pages, was originally undertaken with the view merely of ascertaining the cause of the nuisance arising from the sloblands of Belfast. But we were gradually led into a more extended inquiry, which has embraced not only a study of the chemical changes which occur when *Ulva latissima* ferments, but in addition, an examination of the composition and characters of the weed itself, the isolation of the products of its fermentation, and attempts to isolate the particular organisms giving rise to these products; and finally we have endeavoured to ascertain, both experimentally and by an examination of localities in which the weed is either present in quantity or is virtually absent, the relationship of *Ulva latissima* to the pollution of sea water by sewage.

For the sake of clearness and convenience we shall give the result of our inquiry into these different questions in a somewhat different order from that in which they were obtained.

The Chemical Changes which occur when *Ulva latissima* ferments.

A quantity of the fresh weed was carefully washed in several changes of ordinary tap water until free from shells and debris of various kinds,* and it was then distributed between two flasks, one of which was filled with tap water and the other with sea water, care being taken to get rid of all air adhering to the weed. A well fitting (paraffined) cork was then attached to each of the flasks, and through the cork a gas delivery tube passed, which dipped into a small mercury pneumatic trough and under an inverted test-tube full of mercury. The flasks, with their attachments, were then left in the laboratory at ordinary (winter) temperatures.

After some six weeks the contents of the flask containing the *ulva* and sea water began to evolve gas, and a few days later they blackened, while those of the flask containing *ulva* and tap water gave off gas some days later, and no blackening subsequently occurred.

Some of the liquid from the first flask was driven over along with the gas, and when the test-tube became full of the latter, the liquid escaped on to the surface of the mercury in the pneumatic trough. It was found to be strongly acid, and as it evaporated, smelt of butyric acid. The gases from this flask were examined after an interval of about three months had elapsed since starting the experiment, and were found to consist mainly of hydrogen, carbonic anhydride, sulphuretted hydrogen, and nitrogen.

These preliminary experiments gave a distinct clue to the nature of the chemical changes which the weed suffers when it rots on the foreshore in a moist condition, as well as to the cause of the nuisance to which it then gives rise.

It is clear that an acid is produced in the first stage of the fermentation process, while at a later period, and probably by a distinct fermentative act, sulphides and sulphuretted hydrogen are formed, either by the reduction of the sulphates present in the weed itself or in the sea water, or from the albuminoids contained in the former—these sulphides reacting on the iron compounds in the tissues of the weed to give ferrous sulphide. The latter would no doubt be attacked by the acid, with evolution of sulphuretted hydrogen, and thence the nuisance. As a result of these preliminary experiments, we decided to investigate the quantitative composition of the gases evolved from the fermenting *ulva*, and also to isolate and identify the butyric acid.

To obtain the gases, the same arrangement was employed as before, only the flasks were placed as soon as charged in an incubator at blood heat. Under these circumstances gases began to come off in 48 hours, and were then rapidly evolved.

The following analyses were made:—

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* That others have noticed the occurrence of this seaweed in polluted sea water, and the nuisance which may arise from it, is shown by the following letter which we received from Professor Hartley, F.R.S., of the Royal College of Science, Dublin, during our investigation on the subject:—

"Professor Johnson has shown me your letter *in re* the sewage of Belfast and the shore weed. That weed is never seen on any shore unless sewage runs into the water. The stronger the sewage and the greater its volume the more luxuriant its growth. I have observed this during the last twenty years in England, Wales, Ireland, and Scotland. About eight years ago I washed some of the weed in fresh water and placed it in a bottle of the same. In about twenty-four hours the bottle was opened and the contents found to be in an exceedingly offensive state.

"A paper of mine in the Proc. Roy. Soc. Edinburgh, session 1895-96, touches upon this matter."

Nothing, however, appears to have been published on the subject, and we are under the impression that most botanists consider *Ulva latissima* as characteristic rather of brackish than of polluted sea water.

* The weed, as obtained by us from the Belfast foreshore, was nearly always infested with minute spiral shell-fish, which feed upon it, and eat out circular holes.

ANALYSIS of GASES evolved from *Ulva latissima* fermenting in Sea Water.*

	I. (Collected 5 days after incubation, at 37° C.)	II. (Collected 12 days after incubation, at 37° C.)
Volume of gas taken	14·0 c.c.	16·55
After addition of potash	8·0 „	8·45
After addition of pyro	8·0 „	8·45
Oxygen then added	13·7 „	11·55
After explosion	*10·0 „	*7·65
CO_2 found	6·0 c.c.	8·10
O_2 „	None	None
H_2 „	7·8 c.c.	8·23
N_2 „	0·2 „	0·22
	14·0 c.c.	16·55
Percentage composition.		
CO_2	42·8 c.c.	48·94
H_2	55·7 „	49·73
N_2	1·5 „	1·33
	100·0 c.c.	100·00

* The gas remaining after explosion contained no CO_2.

No sulphuretted hydrogen was present in the gases, which, as their analyses indicate, consisted entirely of carbonic anhydride and hydrogen. Owing to the solubility of carbonic anhydride in water, it was to be expected that the gases collected at first would contain a lower proportion of this constituent than was actually evolved. Only when the liquid in the flask had become saturated with carbonic anhydride would the gaseous products of the fermentation make their way into the collecting tube in their proper proportions, and this state appears to have been reached when the second analysis was made. Its results show the carbonic anhydride and hydrogen to be present practically in the same proportions by volume or in equi-molecular proportions.

The fermentation of grape sugar by the *Baccillus butyricus* is usually represented by the equation

$$C_6H_{12}O_6 = 2CO_2 + 2H_2 + C_4H_8O_2;$$

and, as we have already mentioned, before we had made any gas analyses, the production of butyric acid had been indicated.

A qualitative examination of the contents of the flask after fermentation gave further evidence of the production of the acid, for on distilling them with sulphuric acid an acid liquid passed over, and this, when neutralised with soda and evaporated to dryness, gave a solid residue, which, when warmed with strong sulphuric acid, emitted a distinct odour of butyric acid. Also when it was warmed with strong sulphuric acid and alcohol, the characteristic odour of butyric ether became apparent.

We should probably not have pursued the question further had it not been for the results of a quantitative analysis of what we supposed to be calcium butyrate obtained as follows:—

Some of the *ulva* was well washed and packed into a flask, which was then filled with sea water and the mixture fermented in an incubator at 37° C. until gas evolution ceased. The liquid was then strained off from the seaweed through a cloth filter, distilled with sulphuric acid, the distillate boiled with excess of calcium carbonate, filtered, and evaporated to dryness. Weighed portions of the carefully dried residue were then ignited with strong sulphuric acid, with the following results:—

0·2546 grm. gave 0·1883 grm. $CaSO_4$ = 0·554 grm.
Ca = 21·75 % Ca.
0·3695 grm. gave 0·2681 grm. $CaSO_4$ = 0·0788 grm.
Ca = 21·34 % Ca.

Anhydrous calcium acetate requires	25·32 % Ca
„ „ proportionate requires	21·50 „
„ „ butyrate requires	18·70 „

These results indicated that propionic and not butyric acid had been produced, and the matter seemed worth further investigation, as there appears to be some doubt as to a propionic fermentation from crude vegetable substances, and it is certainly not mentioned in modern chemical or bacteriological text-books. On the other hand, in the older chemical works such a fermentation is mentioned. Thus in Wurtz's *Dictionnaire de Chimie* the following statements are made under the article *Acide Propionique*:—

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(1) Redtenbacher obtained propionic acid by exposing glycerine and yeast for several months at 20--30° C. [*Liebig's Annalen*, 57 (1845), p. 174.]

(2) Keller, by fermenting bran and scraps of leather with chalk. [*Liebig's Annalen*, 73 (1850), p. 205.]

(3) Putrefaction of peas or lentils gives propionic and butyric acid. [Boehme, *Journ. prakt. Chem.*, 40 (1877), p. 278.]

(4) Fermentation of calcium tartrate. [Noellner, *Liebig's Annalen*, 38 ( ), p. 299. Nicklès, *ibid.*, 61 ( ), p. 343. Dumas, Malaguti, and Leblanc, *Comp. Rend.*, 25 ( ), p. 781.]

(5) Propionic acid is stated to be produced by the fermentation of glycerine and of sugar under certain circumstances. [Strecker's *Lehrbuch der organischen Chemie*, 5th edition (1867), p. 159.]

While in Richter's *Organic Chemistry* (English translation, 1900) none of these methods are mentioned, the only process of a similar kind for the production of the acid there alluded to being the fermentation of calcium malate and lactate.

We therefore decided to prepare a quantity of the acid or acids which the fermenting *ulva* gives rise to, and to submit them to a careful examination.

Accordingly, a considerable quantity of the well-washed seaweed was fermented with sea water at 37° C. in large flasks until no further evolution of gases occurred, which required about fourteen days. The resulting fluid was drained off from what remained of the seaweed and distilled with dilute sulphuric acid until traces of hydrochloric acid began to come over. This distillate was neutralised with caustic potash and evaporated to dryness, when about 25 grms. of solid residue were obtained. Experiments with weighed quantities of a known sample of potassium butyrate indicated that the best method for extracting the acid was to treat a strong aqueous solution of the salt with sulphuric acid, and then to extract with ether; distillation of the dry salt with concentrated sulphuric acid leading to considerable charring and loss.

The dried residue was therefore dissolved in 80 c.c. of water, the resulting solution filtered and mixed in a separating funnel with 40 c.c. of strong sulphuric acid, when an oily liquid rose to the surface. The contents of the separating funnel were then extracted six times with well-washed ether, the etheral extracts filtered and distilled from a water-bath.

The remaining liquid was submitted to fractional distillation, and after three fractionations, the bulk distilled over between 140—150° C. The lower boiling portions were treated with phosphoric anhydride and separately fractionated.

They yielded three fractions, which were collected at the following temperatures:—

(1) 110°—125°
(2) 125°—150°
(3) 150°—165°

The main portion of the distillate from the first fractionation weighed 4·7 grms., and had an odour which closely resembled that of a known sample of propionic acid.

It was boiled with water and barium carbonate until neutralised, the resulting solution filtered and evaporated on a water-bath to a syrup. Its behaviour now was curious. Some of the syrup was dissolved in a little alcohol and ether was then added, when it was reprecipitated apparently in the same condition. A drop of the syrup exposed for several hours also dried up to a gummy mass which refused to crystallise. But the main quantity of syrupy liquid suddenly solidified on stirring. The resulting crystalline mass was washed with cold alcohol two or three times and was then dried. It behaved in precisely the same way as a known specimen of barium propionate. Thus it readily dissolved in cold water; and on adding alcohol to a concentrated solution thus obtained, brilliant crystals separated out, which, when examined under the microscope, had very characteristic forms, being either quadratic octohedra or combinations of the octohedra with quadratic prisms. Its analysis, however, showed that it contained small

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quantities of an impurity which obstinately adhered to it, as the following figures show:—

Analysis of Barium Salt dried at 100° C. until of constant weight.

(1) 0·5153 grm. gave 0·4190 grm. $BaSO_4$ = 0·2464 grm. Ba = 47·8% Ba

[The salt had been washed several times with cold alcohol.]

(2) 0·2000 grm. gave 0·1623 grm. $BaSO_4$ = 0·09543 grm. Ba = 47·71% Ba.

[The salt, after washing with cold alcohol, had been boiled with alcohol.]

(3) 0·2648 grm. gave 0·2156 grm. $BaSO_4$ = 0·1268 grm. Ba = 47·87% Ba.

[In addition to the treatment to which (2) had been submitted, this portion of the salt had been recrystallised from water by the addition of alcohol.]

(4) 0·3216 grm. gave 0·2622 grm. $BaSO_4$ = 0·1542 grm. Ba = 47·93% Ba.

[This salt was obtained from the mother liquors of (3), but was recrystallised from water and alcohol.]

Obtained.		Calculated for.	
(1)	47·8	$Ba(C_2H_3O_2)_2$	53·72
(2)	47·71	$Ba(C_3H_5O_2)_2$	48·41
(3)	47·87	$Ba(C_4H_7O_2)_2$	44·05
(4)	47·93		

In order still further to identify the propionic acid, a quantity of the silver salt was obtained by decomposing a solution of 2 grams of the barium salt with the equivalent quantity of silver nitrate. The resulting white precipitate was washed on a filter until the washings gave no precipitate with sulphuric acid, and crystallised from hot water.

Analysis of Silver Salt dried in the desiccator.

(1) 0·232 grm. gave on ignition 0·1305 grm. Ag = 56·25%

(2) 0·0720 grm. gave on ignition 0·0400 grm. Ag = 55·55%

[obtained from the mother liquors of No. 1].

(3) 0·3633 grm. gave on ignition 0·2141 grm. Ag = 58·98%

[obtained by further evaporation of the mother liquors from No. 2].

Per cent. Ag obtained.		Per cent. Ag calculated for.	
(1)	56·25	$AgC_2H_3O_2$	64·66
(2)	55·55	$AgC_3H_5O_2$	59·66
(3)	58·93	$AgC_4H_7O_2$	55·38

It is evident from these figures that some butyrate clings obstinately to the propionate, and owing to its relative insolubility is precipitated first, the bulk of the propionate being found in the mother liquors.

A qualitative reaction was next employed for the identification of the propionic acid.

If this acid is boiled with excess of litharge and the solution allowed to remain in the cold for some time in contact with the litharge, a basic lead salt is produced, which is more soluble in cold than in hot water, and hence is precipitated on boiling the solution.

Comparative experiments tried both with a known sample of propionic acid and with some of the fraction mentioned above, boiling between 125°-150°, give precisely similar results when submitted to this test, a white powdery salt being precipitated from each.

The three fractions obtained from the lower boiling portions of the acids obtained from the fermenting *ulva* were examined as follows.

A roughly graduated pipette was made, and with it the same volume—about 0·2 c.c.—of each of the fractions was removed, weighed, diluted with water, titrated with $\frac{N}{10}$ baryta, the titrated fluid evaporated to dryness, and heated at 100° C. until of constant weight, then ignited with sulphuric acid, and the resulting barium sulphate weighed.

The following table contains the results, calculated in such manner as to be comparable both with each other and with the theoretical quantities required for acetic, propionic, and butyric acid respectively.

Fraction.	Acid taken.	c.c. $\frac{N}{10}$ Baryta required for 1 part of acid.	Weight of Dry Barium Salt from 100 parts of acid.	Percentage of Barium.
110°-125° C.	0·2430 grm.	126·1	177·3	50·68
125°-150° C.	0·2332 ,,	129·1	189·7	48·54
150°-165° C.	0·2192 ,,	113·7	182·2	44·70
$C_2H_4O_2$	requires	167·0	212	53·72
$C_3H_6O_2$	,,	135·0	191	48·41
$C_4H_8O_2$	,,	113·6	181	44·05

Although these results are not entirely satisfactory or concordant, they certainly point to the occurrence of acetic as well as propionic and butyric acids among the products of the fermentation of *ulva* in sea water, but the identification of the former with certainty was not possible, owing to the smallness of the low boiling fraction and the difficulties attending the separation of a given acid of the fatty series from a mixture with its homologues. But the boiling point and higher specific gravity of the low boiling fraction, as well as the percentage of barium found in the barium salt obtained from it, can scarcely be accounted for except on the assumption that it contained acetic acid.

Our experiments on the fermentation of *Ulva latissima* in sea water thus afford evidence that at least three members of the fatty series of acids are produced. Of these, however, propionic acid is formed in by far the largest quantity.

The Composition of the Tissues of *Ulva latissima*.

The occurrence of the *ulva* in two localities (Dublin Harbour and Belfast Lough) in considerable quantities where crude sewage makes its way into the sea, and the experiments just recorded in the products of its fermentation, raised several questions which rendered it advisable to make both an ultimate and proximate analysis of its tissues. Thus, if the growth of the weed in quantity is induced by pollution of the sea water by sewage, the weed itself might possibly be found to contain a higher proportion of nitrogen than is present in other seaweeds which luxuriate only in pure sea water.

Again, as regards the products of its fermentation. What substance present in its tissues gives origin to the propionic and other acids? Is it a carbo-hydrate, and, if so, what carbo-hydrate, and whence come the ferrous sulphide and sulphuretted hydrogen which are produced abundantly in the later stages of the fermentation?

Ultimate Analysis.—For the ultimate analysis a considerable quantity of the seaweed was collected, and each frond separately washed in tap water, and finally with distilled water. The seaweed was then drained, pressed between filter-paper, dried in the air, and then in a desiccator until it was quite brittle, when it was reduced to a fine powder in a mortar, and the powder then dried in a weighing bottle. All the different determinations were made on portions of the same stock of seaweed thus prepared.

Ash.—To obtain the ash, weighed quantities of the weed were ignited in a platinum crucible until the residue was of constant weight. We give below all the results obtained, but may remark that (2) and (3) are probably too low, from loss of sodium or potassium chloride.

(1) 0·6502 grm. yielded 0·1001 grm. ash = 15·39%
(2) 0·4582 ,, ,, 0·0667 ,, ,, = 14·56 ,,
(3) 0·4753 ,, ,, 0·0698 ,, ,, = 14·68 ,,
(4) 0·4958 ,, ,, 0·0762 ,, ,, = 15·37 ,,
(5) 0·3248 ,, ,, 0·0499 ,, ,, = 15·36 ,,

Mean 15·07%

Total Nitrogen.—by Dumas' method.

(1) 0·5280 grm. gave 27·6 c.c. nitrogen at 16° C. and 764 mm. = 26·21 c.c. at N.T.P. = 0·032836 grm. = 6·22%.

(2) 0·1986 grm. gave 10·5 c.c. nitrogen at 19° C. and 764 mm. = 9·87 c.c. at N.T.P. = 0·01237 grm. = 6·23%.

(3) 0·7122 grm. gave 36·6 c.c. nitrogen at 17° C. and 764 mm. = 34·63 c.c. at N.T.P. = 0·043382 grm. = 6·09%.

Mean = 6·18 ,,

Carbon and Hydrogen.—The powdered weed was ignited in a closed combustion tube with chromate of lead.

(1) 0·6127 grm. gave { 0·2937 grm. H_2O = 0·0326 grm. H = 5·33 %; 0·7936 „ CO_2 = 0·2164 „ C = 35·32 „

(2) 0·6560 grm. gave { 0·3075 „ H_2O = 0·0342 „ H = 5·21 „; 0·8413 „ CO_2 = 0·2294 „ C = 34·98 „

Mean % of hydrogen = 5·27
„ carbon = 35·15

The composition of the tissues of *Ulva latissima* deduced from the preceding analysis is—

Carbon		35·15
Hydrogen		5·27
Nitrogen		6·18
Oxygen (by difference)		38·33
Ash	containing { Sulphur 3·21; Iron 2·20	15·07
		100·00

Proximate analysis.—The attempts which we have made to isolate any definite compounds as proximate constituents of the *ulva* have not been very successful, but it is only fair to ourselves to say that we have not had time to study the matter exhaustively.

Various experiments were tried with different solvents.

When boiled with water the seaweed does not soften nor suffer apparently any considerable change, and no blue colour is produced when the infusion is treated with iodine.

A special experiment was made to ascertain whether any carbohydrate was present capable of ready hydrolysis into a sugar, and for this purpose a quantity of the washed *ulva* was treated for a week in the cold with water containing 5 per cent. of sulphuric acid. The extract was then drained away from the seaweed, excess of barium carbonate added, the solution filtered and evaporated.

During the evaporation white amorphous matter separated and oily globules also. The dried residue was treated with a little water, the solution filtered and heated on a water-bath with 2 grms. of crystallised phenyl-hydrazine hydrochlorate, and 3 grms. of sodium acetate, but no trace of a crystallised osazone could be obtained. For the sake of comparison, a mixture of 1 grm. of ordinary dextrose with the same quantities of phenyl-hydrazine hydrochlorate and sodium acetate and water was heated and gave abundance of the yellow osazone

The amorphous matter turned out to be magnesium carbonate, with practically no organic matter.

The remainder of the *ulva*, after treatment with acid, was well washed with distilled water, and then digested in the cold for a week with 5 per cent. caustic soda solution. The resulting brown liquid was coloured green by a slight excess of hydrochloric acid, and a brownish flocculent precipitate was produced.

By treating the *ulva* with alcohol or ether, the chlorophyll, etc., are only very slowly dissolved. In a preliminary experiment some of the dry seaweed was submitted to the boiling reagent in an extraction apparatus for a week—ether first, and alcohol later—but at the end of that time it was still green in parts.

In a later experiment, 14 grms. of the *ulva*—washed, dried, and roughly powdered—were boiled in a flask with inverted condenser for a week with alcohol. Each day the alcoholic extract was filtered off and distilled from the same (tared) flask, the distillate being again employed for the extraction.

The dried alcoholic extract weighed 2·35 grms., or about 17 per cent. of the weight of the original dried seaweed.

What remained of the latter was then dried and digested in the cold for eight days with a 5 per cent. solution of caustic potash. The liquid was then filtered off through a weighed filter, and the residue of seaweed collected on the latter, well washed and weighed. It amounted to about 7 grms.

On the supposition that alcohol removed all the chlorophyll, fat, etc., and the caustic potash the albuminoids, the composition of the dried seaweed may be represented thus:—

Chlorophyll, fats, etc.	17 %
Albuminoids or "proteids"	33 „
Cellulose	50
	100 %

If the percentage amount of nitrogen found in the *ulva* be multiplied by the factor 6·25 (often employed for calculating in such cases the "proteids"), the result is 38·6, which is not very different from 33, and it must be remembered that the experiment was only roughly quantitative.

Bacteriological Examination.

From the chemical examination of the products of the fermenting *ulva*, it seemed probable that it was attacked by at least two different species of micro-organisms—the first producing fatty acids together with hydrogen and carbonic anhydride; the second causing the formation of sulphides.

The evidence on this point was tolerably clear, for on several occasions no sulphides were produced at all, and, as a consequence, no blackening of the weed occurred, and no evolution of sulphuretted hydrogen, although fermentation had been active, and fatty acids had been plentifully produced, together with hydrogen and carbonic anhydride. And in all our experiments in which the weed blackened, the acid-producing phase of the fermentation preceded that of the sulphide formation by a considerable interval.

Also, when the *ulva* was allowed to ferment in tap water and not in sea water, the production of sulphides was always delayed, and very often did not occur at all.

Numerous attempts have been made to isolate the organisms causing the two changes, but not with absolute success; and we may take this opportunity to express our thanks to Dr. Lorrain Smith and Dr. Tennant for the assistance they have given us in this branch of the investigation.

Stained preparations of the fermenting *ulva* showed that spore-forming bacilli similar in appearance to *B. tetani* were abundant, but all attempts to isolate them by Koch's plate method or Esmarch's roll tube (anaerobic) cultures, either with ordinary gelatine or agar media, failed, practically no colonies appearing.

A special culture fluid was then made with sea water containing 1 per cent. peptone and 1 per cent. glucose, and (after sterilisation) flasks of this were inoculated (A) with a droplet of the liquid from a tube containing fermenting *ulva* and sea water, and (B) with a minute fragment of the *ulva* itself from the same tube after its contents had been heated for twenty minutes to 80° C., to destroy all but spores.

These cultures when incubated grew, and showed, it was thought, some sign of gas evolution.

After five days agar plate cultivations were made from both, but no colonies appeared. Similar cultivations were made with a medium containing 1 per cent. peptone and 1 per cent. glucose with sea water and agar, both under aerobic and anaerobic conditions, but again without obtaining any definite growth of colonies.

On the other hand, the glucose peptone sea water medium which had been inoculated with a fragment of the fermenting weed, heated to 80° C., developed acid, the amount of which was determined by $\frac{N}{10}$ baryta solution.

10 c.c. after 3 days' incubation at 37° C. required 2·2 c.c. $\frac{N}{10}$ baryta = 0·01628 grms. propionic acid.

10 c. c. after 7 days' incubation at 37° C. required 2·68 c.c. of $\frac{N}{10}$ baryta = 0·0198 grms. propionic acid.

An experiment was then made on a larger scale with this culture fluid, which was sterilised and inoculated with some drops of the liquid from a test-tube containing sea water, glucose, and peptone, and a fragment of the fermenting *ulva*.

The flask containing the inoculated fluid was provided with a cork and an arrangement for collecting any gases which might be evolved, and was placed in an incubator, where it remained for two or three weeks, but no appreciable quantity of gas came off. The contents of the flask were then distilled with sulphuric acid, the distillate boiled with excess of barium carbonate, and the filtered solution evaporated to dryness. A small quantity of a gummy barium salt remained, which qualitatively resembled the crude barium salt obtained from the fermentation of the weed, but its

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amount was not sufficient for any quantitative experiments.

Attempts were next made to obtain colonies of the micro-organism by employing a substratum of the weed itself. Some fronds of the *ulva* were pressed and dried, and then attached to glass plates by weak gelatine solution. The plates so prepared were next sterilised by heat, and three of them treated as follows:—

On No. 1 some sterilised gelatine was poured, previously inoculated with a droplet taken from a tube containing sea water and a fragment of *ulva* which had fermented, but had not blackened. On No. 2 some sterilised agar was poured, which had been similarly inoculated; and on No. 3 the same medium, inoculated from the same source, which had previously been heated to 80° C. for twenty minutes.

Of these three plate cultivations, well-marked colonies appeared on Nos. 1 and 2. No. 3, was doubtful, and too much dried up.

Two colonies from No. 1 and four from No. 2 were planted out in the tubes containing fragments of *ulva* and sea water previously sterilised. In three days the tubes inoculated with No. 1 had given off a good deal of gas, and one of those inoculated with No. 2 had also given off gas and its contents were turbid.

It seems probable, therefore, that by this method the organism causing the acid fermentation was isolated. Regarding the second or sulphide-forming phase of the fermentation, as we have already said, it always occurred much later than the first or acid phase, and frequently did not take place at all; and although the presence of sea water does not appear to be absolutely essential to its occurrence, yet undoubtedly it materially assists it, and for that reason we are inclined to believe that the sulphides owe their origin chiefly to sulphates in the water, and possibly in the *ulva* itself, and not to the albuminoids present in such abundance in the weed.

There is also some evidence to show that the organisms concerned in the process occur in the mud of the foreshore where the *ulva* is found, and not in the sea water.

The following experiment brings out these facts.

A number of test-tubes were partly filled with sea water, and others with tap water, and in each a piece of *ulva* was placed previously well washed in tap water; all air bubbles adhering to the weed were got rid of by pressure with a glass rod.

A cotton-wool plug was then inserted in the mouth of each tube, which was made to support a strip of paper moistened with lead acetate, which hung about an inch above the surface of the liquid.

In addition to five such tubes containing the washed weed and sea water, and five containing the washed weed and tap water, two similar tubes were prepared containing unwashed weed, one with sea water and the other with tap water. All the tubes were then placed in the incubator. In 24 hours the acid phase of the fermentation had commenced in all the tubes, indicated by the inflation of the weed by the evolved gases.

In 48 hours the lead paper in the tube containing the unwashed weed and sea water had begun to blacken distinctly, and that containing the unwashed weed and tap water was also tinged, though faintly. In 72 hours the lead papers in all the sea water tubes were strongly blackened, but those in the fresh water tubes remained unaffected, except the one in the tube containing the unwashed weed. In 168 hours the unwashed weed in sea water was itself beginning to blacken, but the contents of the tap water tubes had still only faintly blackened their lead papers.

Even after a month, the difference in the appearance of the contents of the two sets of tubes was very noticeable. Zelinsky* has described an organism which he named *Bacterium hydrosulfureum ponticum*, and obtained from the ooze of the Black Sea, which reduces sulphates to sulphides, and evolves sulphuretted hydrogen. He employed a special culture fluid for its growth, containing 1 per cent. solution of ammonium tartrate, 1 to 2 per cent. solution of grape sugar, ½ to ⅓ per cent. of sodium hyposulphite, 0·1 per cent. of potassium phosphate, and traces of calcium chloride.

We prepared some of this fluid and inoculated (sterilised) tubes of it with minute fragments of the following:—

1. *Ulva* which had fermented with sea water for 12 months in a stoppered bottle.

2. *Ulva* which had been fermented with tap water for the same time and under similar conditions.

Lead papers were suspended in the upper part of each tube by cotton-wool plugs, and the tubes then placed in the incubator. We also prepared a similar set of tubes containing ⅓ per cent. of ferrous sulphate instead of the hyposulphite, and inoculated them in the same way. The first series we shall call A and the second B.

In 99 hours the lead papers in all the tubes were blackened except B 2, and a filmy growth was beginning to form on the surface of the liquid in two of the tubes. After a further interval of 24 hours, A 1 was covered with a pink growth, and A 2 with a white growth. A 1 was plated out in ordinary agar medium, but it gave no colonies, but A 2, similarly treated, gave plenty of well-defined colonies. Three of the latter were again plated out and inoculation from the resulting colonies made in tubes containing sterilised *ulva* and sea water, when after 5 days a whitish growth began to appear in the tubes, and 2 days later their contents were giving off sulphuretted hydrogen.

We have not had time to pursue the bacteriological investigation further, which very possibly in more experienced hands might have given more definite results, but we believe that the following conclusions are warranted from our experiments:—

(1) When the *Ulva latissima* ferments in water, it is attacked by a species of micro-organism, which is a spore-forming bacillus, and which probably infests the weed itself. The products of this fermentation consist mainly of propionic acid, but other fatty acids are formed in smaller quantities, together with carbonic anhydride and hydrogen. This micro-organism probably attacks the albuminoids of the seaweed.

(2) The fermenting *ulva* is attacked later by a second species of micro-organism, with the production eventually of ferrous sulphide and sulphuretted hydrogen. It seems probable that these sulphur compounds are produced from the sulphates of the sea water (or those contained in the tissues of the *ulva*), and not from the albuminoids of the seaweed, and that the micro-organisms are derived from the mud of the foreshore where the *ulva* grows.

Our experiments so far do not enable us to decide definitely whether the sulphuretted hydrogen is produced directly from the sulphates (or possibly the albuminoids), or indirectly from the ferrous sulphide, by the action of the organic acids. We are, however, of the opinion that some of the gas at least owes its origin to the second of these two causes.

Ulva latissima in relation to Sewage Pollution.

The evidence which we have collected tending to prove that the occurrence of *Ulva latissima* in quantity in any locality is associated with the pollution of the sea water by sewage is of three kinds.

First, that afforded by the composition of the weed itself, or rather by the proportion of nitrogen it contains. Second, from experiments made on the assimilation of nitrogenous compounds by the growing *ulva* from sea water purposely polluted; and third, from an examination of the localities in which the weed occurs in abundance, and of those from which it is virtually absent.

We shall discuss each of these separately.

1. The proportion of nitrogen in the *Ulva*.—The most interesting and important result of our analyses of the tissues of the weed—and certainly the most surprising one to us—is the extraordinary proportion of nitrogen which they contain. In the following table the percentage of nitrogen in some other (dried) seaweeds is compared with that of the *ulva*, as well as the "proteine," obtained by multiplying the percentage of nitrogen by the factor 6·25.

* Zelinsky, Proceedings of the Russian Physical and Chemical Society, 25, fasc. 5 [1893].

	Percentage of	
	Nitrogen.	Proteine.
Ulva latissima	6·18	38·625
Chondrus crispus (Carragheen Moss):		
Bleached, from Bewlay Evans.	1·524	9·587
Bleached, second experiment.	1·485	9·281
Unbleached, from Ballycastle.	2·142	13·387
Unbleached, second experiment.	2·510	15·687
Gigartina mamillosa, from Ballycastle.	2·198	13·737
Laminaria digitata	1·588	9·925
Rhodymenia palmata (Dulse)	3·465	21·656
Porphyra laciniata	4·650	29·062
Sarcophyllis edulis	3·088	19·300
Alaria esculenta (Murlins)	2·424	15·150
Fucus saccharinus †	2·29	—
„ *digitatus* †	1·46	—
„ *vesiculosus* †	1·57	—
„ *ceramium rubrus* †	2·03	—

* Thorpe's Dict. Appl. Chem. † Wurtz, Dict. d. Chim.

Not only is the proportion of nitrogen in *ulva* extraordinarily high compared with that present in other seaweeds, but also with vegetables generally. Indeed, in nitrogen content it resembles an animal rather than a vegetable product, as will be seen from the subjoined list of a few typical substances:—

	Percentage of Nitrogen about
Animal.	
Meat (dry)	10½
Cheese (dry)	7
Milk (dry residue)	5
Vegetable.	
Peas	4–4½
Clover Hay	3
Wheat	2½
Meadow Hay	2

The farmers on the shores of Belfast Lough have discovered the value of the *ulva* as a manure, and large quantities are carted away by them and used on their land. It no doubt fails in phosphates, but contains the necessary potassium salts. It is probable that it would be greatly improved for most crops by the addition of calcium phosphate or basic slag.

2. Assimilation Experiments.—Our first idea was to contrast the extent of the growth of the *ulva* in pure sea water and in polluted sea water respectively, and accordingly, as far as possible, similar tufts of the growing weed, adhering to stones, etc., and freshly removed from the sea-shore, were placed in two glass aquaria, one of which was filled with the pure sea water of the Irish Channel and the other with the same water to which 2½ per cent. of Belfast sewage had been added. Photographs were then taken of the two tanks, with the object of contrasting them with photographs on the same scale to be taken later.

The result of this experiment was, however, curious, as the weed in both tanks soon became unhealthy and died in a month or two. We believe that the explanation was that in both cases the *ulva* was killed by the strong sunlight to which at times it was exposed, as the two aquaria containing it were placed in a window facing south-west, and the experiment was made in the spring-time.

Since then we have had a specimen of the seaweed growing in a glass dish placed near a window with a northern aspect for months, and as we write, it is still in a perfectly healthy condition. It is a mere frond of the *ulva*, and was picked up on the shore, unattached to any support, and indeed, when we commenced our experiments with it, we were afraid that it would be of no use to us. But this frond has remained in perfect health for seven months, during which time it has been treated with several different specimens of foul sea water, and in the intervals has not been supplied with any pure sea water, for after the failure of our first experiment it occurred to us that a far better method of investigation would be to examine the water in which the weed was growing, and not the weed itself.

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The methods of water analysis are delicate, and by contrasting the composition of samples of sea water both before and after the *ulva* had been allowed to grow in them, it seemed to us that the information we desired ought to be readily obtained.

The following experiments were therefore made:—

The frond of *ulva* employed was well washed for about an hour in running tap water to free it from debris. It was of large size, its area being 147 square inches, or about one square foot, and its active surface therefore twice that amount.

The dish in which it was placed was a circular glass vessel, with flat bottom and vertical sides, 8in. in diameter and 3in. high. It was provided with a cover similar to itself, and it contained in our experiments 1,600 cc. of water. In order to get the frond of seaweed into the dish it was folded across the middle.

Experiment 1.—Assimilation of Ammonia.—A sample of sea water was employed which was collected from a locality in Belfast Lough where several small sewers discharge directly into the sea, and was therefore presumably polluted. The frond of *ulva* was rinsed in the dish with some of this water, which was thrown away, and the dish was then filled with more of the same water, the air bubbles entangled in the folds of the seaweed being got rid of by gentle pressure with a glass rod. Some of the water was analysed before this was done, while after a week had elapsed a quantity of the water was removed from the dish and also analysed.

The results of the two analyses were as follows:—

	Parts per 100,000.	
	Free Ammonia.	Albuminoid Ammonia.
Original sea water	0·046	0·020
After contact with the *ulva* for seven days	0·000	0·020

The seaweed had therefore absorbed every trace of free ammonia from the water, a result which was quite unexpected and highly interesting. On the other hand, none of the albuminoid matter had been absorbed, which, however, is quite in accordance with the known facts regarding plant nutrition. In order to verify this result, the *ulva* was allowed to remain in the same water for another week, when a second analysis was made with precisely the same results as before.

Experiment 2.—Assimilation of Ammonia.—This experiment was made with the view of getting some idea of the rapidity with which the *ulva* can absorb free ammonia from sea water, and also to ascertain whether it can thrive in a very highly polluted water. The frond of *ulva* had remained in the sea water of the last experiment an additional four days, making eighteen in all, and appeared to be quite healthy.

A sample of sea water was collected from the same locality as before, and to it 1 per cent. of sewage was added (obtained from the pumping station at the Belfast Main Drainage Outfall). This mixture gave on analysis the following results:—

	Parts per 100,000.	
	Free Ammonia.	Albuminoid Ammonia.
Sea water, *plus* 1 per cent. sewage	0·030	0·024

But as it contained less free ammonia than was expected, a standard solution of ammonium chloride was added,

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sufficient to bring up the free ammonia to 0·050 parts per 100,000.

The frond of *ulva* was drained from the first sample of sea water and rinsed with this mixture, again drained, and the dish then filled with the same mixture.

It was intended to make a series of analyses of the contents of the dish at intervals of about twenty-four hours, but to our astonishment we found that practically the whole of the free ammonia had been absorbed after a period of only seventeen hours, as the following determination shows:—

—	In 100,000. Free Ammonia.
Sea water, *plus* sewage and ammoniun chloride, after contact with the *ulva* for 17 hours	0·001

With the object of tracing the fate of the albuminoid matters, the weed was allowed to remain for about five weeks in contact with the mixture, while a flask containing the same mixture was also kept during the same interval. Both samples were then analysed, with the following results:—

—	Parts per 100,000.	
	Free Ammonia.	Albuminoid Ammonia.
Sea water *plus* sewage and ammonium chloride, kept for five weeks	0·050	0.016
The same mixture after contact with the *ulva* for five weeks	0·004	0·017

These results further prove that the *ulva* cannot absorb albuminoid matters.

Experiment 3.—Assimilation of Nitrates.—The result of these experiments, as well as other considerations to be mentioned presently, induced us to extend our inquiry somewhat further, in order to ascertain whether the *ulva* can absorb nitrogen in the form of nitrates with the same ease and rapidity as it assimilates that element as ammonia.

The same frond of *ulva* was again used which had now been under observation in the dish for six months. In the interval from the last experiment the water in which it was growing had been changed only once. On examination it was found that, owing to the inflation of some of its under surface by evolved oxygen, a portion of the frond had become quite dry and almost bleached. We thought it highly probable that it was no longer in a sufficiently healthy condition for further experiment, but having no other specimen at hand, we decided to test its vigour by its power of absorbing ammonia.

Some fresh sea water was therefore obtained and examined as follows:—200 c.c. were distilled until 100 c.c. had passed over, and 50 c.c. of this distillate were Nesslerised for the free ammonia. The residue left in the distilling flask was then diluted to the original volume (200 c.c.) with ammonia free water, and treated with zinc-copper couple for twenty-four hours at ordinary temperatures, then poured off, again distilled, and the distillate Nesslerised. The result of the analysis were as follows:—

—	Parts per 100,000 Nitrogens.	
	Free Ammonia.	Nitrate.
The sample of sea water contained	0·005	0·006

Sufficient ammonium chloride was added to this sea water to bring up the nitrogen as free ammonia to 0·042 parts per 100,000, and this strength was verified by a determination made as before.

The frond of *ulva* was now drained from the sea water in which it had been immersed for some months, rinsed with the new sample prepared as just described, and the dish then filled with the latter.

After 24 hours, 200 c.c. of the water were removed from the dish, distilled, and the distillate Nesslerised, when no free ammonia was found, proving that the seaweed was still in a perfectly vigorous condition. This was also shown by the copious evolution of oxygen which had occurred from it, the gas remaining entangled in the folds of the frond.

The water in the dish was next poured off, and sufficient of a standard solution of potassium nitrate added to it to bring up the nitric nitrogen to 0·05 parts per 100,000, when it was emptied back again. The frond of *ulva* was now in contact with ammonia-free sea water containing nitrates, and was allowed to remain thus for 70 hours, when a portion of the water was removed from the dish, and the nitrates determined by the same process as before. The water was found to contain 0·005 parts of nitric nitrogen, showing that the *ulva* had absorbed 90 per cent. of the amount originally present.

The results of the preceding experiment leave no doubt as to the energetic power which *Ulva latissima* possesses of absorbing nitrogen from polluted sea water, both in the form of ammonia and of nitrates. They also clearly demonstrate that this seaweed can flourish in highly polluted water; and, in addition, they lend a good deal of support to the theory which we had gradually been led to form, that the occurrence of the *ulva* in quantity in a given locality may be regarded as a sign of sewage pollution.

From the results of these experiments it is possible to calculate the rate of growth of the *ulva* under the existing conditions; for, as its tissues contain 6·18 per cent. of nitrogen, it is obvious that the nitrogen lost by the water in which it was placed, multiplied by the factor $\frac{100}{6.18}$, gives the weight of the seaweed formed.

Thus, in experiment 2, the water lost 0·049 per 100,000 of free, or saline, ammonia in 17 hours. This is equivalent to 0·0404 parts of nitrogen per 100,000; and, as it was removed from 1,600 c.c. of water, its actual weight was $0{\cdot}0000404 \times 16 = 0{\cdot}0006464$ grm., and this, multiplied by the factor $\frac{100}{6{\cdot}18}$, gives 0·0104 grm., or about 1 centigram., as the actual weight of seaweed formed.

A series of determinations showed that 1 square inch of the dried *ulva* weighs, on an average, 0·009 grm., so that in this experiment $\frac{0.0104}{.009}$, say, 1·1 square inches of the *ulva* were formed, which is equivalent to nearly 0·8 per cent. of the original frond.

We hope to make further experiments in order to ascertain whether the rate of nitrogen assimilation is constant, or varies with the concentration, and also to what extent the rate is affected by differences in illumination.

3. The localities in which *Ulva latissima* occurs in quantity contrasted with those from which it is virtually absent.—We may first of all draw attention to two particular localities which have come more immediately under our observation where this seaweed is abundant, and one from which it is almost entirely absent because an examination of the conditions obtaining in these offers some very striking evidence in favour of the view mentioned above, viz., that the occurrence of the *ulva* in quantity is an indication of sewage pollution.

The first two localities we refer to are Belfast Lough and a part of Dublin Bay, and the second is Strangford Lough.

Belfast Lough.—According to the statements of some of the older inhabitants of the neighbourhood, *Ulva latissima* was not present in former times in the very large quantities in which it now occurs in the upper reaches of the Lough, but the *Zostra marind*, or sea grass, now found only in small quantities, was abundant

Up to the year 1889 the bulk of the sewage of the city of Belfast was allowed to flow directly into the Lagan river. But in that year a new drainage system was inaugurated, by which the greater part of the sewage is collected in two main channels, and from them pumped into a tank, the contents of which are discharged (on the ebb-tide only) through a submarine culvert opening some distance seawards. Belfast, as everyone knows, has grown with remarkable rapidity, and there can therefore be no question that for that reason alone very much more sewage makes its way into the Lough now than formerly, and this amount has undoubtedly been increased since the introduction of the main drainage scheme, the Lagan river no longer acting as a settling-tank in which the bulk of the sewage solids were deposited.

The tides in the upper reaches of the Lough are sluggish, and from float experiments made by the engineer to the Harbour Board, it would seem that the greater part of the sewage does not make its way out of the Lough on the ebb-tide, but having drifted a certain distance seawards, is washed backwards by the flood-tide in a bifurcating stream, which distributes it over a wide area.

In Dublin Bay the conditions under which *Ulva latissima* occurs in quantity are both interesting and significant.

Broadly speaking, the upper reaches of the Bay are divided artificially into two portions by the so-called Pigeon House wall, which extends for more than a mile and a half in an easterly direction, and terminates in Poolbeg lighthouse. A second wall, called the North Bull wall, juts out from the northern shore of the Bay at Dollymount, and extends in a S.E. direction to within about 1,000 feet of Pool Beg lighthouse, terminating in a second lighthouse, called the Bull. The northern part of the Bay thus almost enclosed by the two walls forms the harbour. On the other hand, the southern portion of the Bay is quite open.

The harbour receives not only the waters of the Liffey river, into which the major portion of the city sewage at present flows, but also those of the Tolka river, which is polluted by a large sewer running into it close to its mouth, while another large sewer discharges directly on to the northern shore close to the city, as well as a considerable number of smaller sewers the whole way thence to Dollymount.

On the other hand, no sewers of any magnitude (if, indeed, any at all?) discharge their contents into the southern portion of the Bay until Blackrock and Kingstown are reached, which are quite at its mouth. Thus, broadly speaking, the northern portion of Dublin Bay consists of a polluted area, while the southern portion is unpolluted. Now, plenty of the *ulva* is found on the northern shores of the harbour, and is washed up along the Clontarf foreshore, where, as in Belfast Lough, it rapidly putrefies in warm weather, and gives rise to a nuisance. On the other hand, the southern portions of the Bay seem to be quite clear of the seaweed until Blackrock and Kingstown are reached, where it is found in fair quantity.

On Plates 2 and 3 we give charts of these two localities (Belfast Lough and Dublin Bay), on which we have marked in black those areas over which the *ulva* is chiefly distributed. It must be recollected that most of this seaweed is unattached by any stalk, and drifts about from place to place. Hence no chart can be drawn to represent where it will be found on all occasions, and the Plates must, therefore, in respect of the occurrence of the weed, be regarded merely as diagrams. Strangford Lough, which is quite close to Belfast Lough, resembles the latter in extent of area, and also in the large surfaces uncovered in its upper reaches at low water. It differs from it, however, in that no large town is situated on its banks. In this Lough *Ulva latissima* is practically absent. The above-mentioned facts seem to offer strong *primâ facie* evidence that the growth of *Ulvâ latissima* is associated with sewage pollution of sea water, and as a consequence that its occurrence in quantity in a particular locality may be regarded as an indication of sewage pollution. There can, at all events, be no doubt as to the nuisance which this seaweed can at times gives rise to, which closely resembles that proceeding from very foul sewage. And there can also be no doubt as to the extraordinary powers of nitrogen assimilation which it possesses.

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ON THE NATURE AND SPEED OF THE CHEMICAL CHANGES WHICH OCCUR IN MIXTURES OF SEWAGE AND SEA-WATER. By PROF. E. A. LETTS, D.Sc., Ph.D.; R. F. BLAKE, F.I.C., F.C.S.; W. CALDWELL, B.A.; and J. HAWTHORNE, B.A.

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(Communicated by Dr. W. E. Adeney, F.I.C., F.C.S.)

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It need scarcely be said that one of the commonest methods adopted by towns situated on the coast, for the disposal of their sewage, is to run it without treatment of any kind directly into the sea.

Mr. Richard Hassard has given us the following list of the chief towns in Great Britain which adopt this plan:—

Aberdeen.	Margate.
Dundee.	Dover.
Berwick-on-Tweed.	Folkestone.
Newcastle.	Hastings.
Sunderland.	Brighton.
Scarborough.	Portsmouth.
Blackpool.	Sidmouth.
Liverpool.	Teignmouth.
Birkenhead.	Devonport.
Hull.	Swansea.
Great Grimsby.	Bristol.
Yarmouth.	

And to them may be added the following Irish towns.—

Belfast.	Waterford.
Dublin.	Cork.
Londonderry.	Limerick.
Wexford.	Galway.

The nature of the chemical changes which occur when sewage is thus treated, the speed at which they take place, the conditions which modify either the changes themselves, or the rate at which they occur, and the circumstances under which a nuisance may arise, are questions all of which are not only of scientific interest, but also of practical importance.

In order to decide these questions, and especially the effects of varying dilution and temperature on the speed, and possibly, on the nature of the chemical changes occurring, a very large amount of experimental work would be necessary, and for this reason the results which we now bring forward must be considered as chiefly of a preliminary nature.

In order to trace the nature of the chemical changes which occur when mixtures of sewage and sea-water are left to themselves, and the speed with which they take place, we have experimented under both fully aerobic and partially aerobic conditions. Indeed, in the second series of experiments, the conditions were, in one sense anaerobic, as no air, as such, was admitted to the mixture, which, however, contained the gases its constituents had dissolved from the atmosphere.

The method of investigation adopted in the second series of experiments was that originally employed by Dr. Adeney in his very important researches on "The Course and Nature of Fermentative Changes in Natural and Polluted Waters and in Artificial Solutions." Briefly stated, this method consists in analysing, from time to time, the gases boiled out *in vacuo* from the polluted water or artificial solution, and thus ascertaining the amount of dissolved oxygen which disappears, and that of the carbonic anhydride which is produced.

In our experiments with mixtures of sewage and sea-water, we have adopted Adeney's method; and for boiling out and analysing the dissolved gases, we have used an apparatus similar to his own, and, thanks to his kindness, largely constructed under his own supervision. Simultaneously with the gas analyses, determinations were made in the same sample of the mixture of —

(1) The "free" and "albuminoid" ammonia.

(2) The "oxygen absorbed" from acid permanganate during four hours at 80° F.

(3) The nitrites by the phenylene diamine process.

(4) The nitrates by the zinc-copper couple method.

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In commencing a series of experiments, a stock of the mixture of sewage and sea-water was made, and a series of bottles filled to the brim with it and tightly stoppered.

These were then completely immersed in water contained in a zinc bath, the temperature of which was regulated by a sensitive thermostat and an automatic (water-driven) stirrer.

In analysing the dissolved gases, a given quantity (200 c.c) of the mixture was withdrawn from one of the bottles through a tube plunged to the bottom, and rapidly transferred to the boiling-out apparatus In this way, only the lower layers of liquid were removed for analysis, and contact of the sample with air avoided. As in Adeney's experiments, a small quantity of sulphuric acid was added before boiling out the gases, to decompose any bicarbonates present.

In the aerobic experiments, a large confectioner's jar was used to contain the mixture, and this was heated in a water-bath. Inside the jar a thermostat was placed, as well as a stirrer, both being made of glass. For obvious reasons no analyses of dissolved gases were made in this series of experiments.

The sea-water used in all the experiments was collected from a spot (near Black Head) just outside Belfast Lough, and at a time of the tide when there was a strong current from the Irish Channel, so that the water was uncontaminated. Three samples of sea-water (collected on different occasions) were employed which we shall call 1, 2, and 3. The following determinations were made in them:—

SEA-WATER.

No. of Sample.	Temperature when collected in ° C.	(In cubic centimetres per litre at N. T. P.) Dissolved Gases.				(In parts per 100,000.) Unoxidized Nitrogen as			Oxidized Nitrogen as Nitrates.	"Oxygen absorbed" in 4 hours at 80° F.
		CO_2.	O_2.	N_2.	Total.	Free NH_3.	Albd. NH_3.	Total.		
1	8·8	45·20	6·95	12·16	64·31	·0013	·0058	·0071	—	0·1328
2	9·9	—	—	—	—	·0013	·0066	·0079	·0033	0·0952
3	11·0	—	—	—	—	—	—	—	—	—

The sewage was obtained from the Belfast Main Drainage system, close to the Outfall Works, either from the sewer itself or from the tank into which the sewage is pumped previous to its discharge into the Lough on the ebb tide. Three samples were employed, each of which was filtered previous to its employment. The following determinations were made:—

FILTERED SEWAGE.

No. of Sample.	In parts per 100,000. Total Solids.	Nitrogen as— Free NH_3.	Albd. NH_3.	Total.
1	469·8	1·82	0·15	2·97
2	243·7	1·25	0·59	1·84
3	93·5	0·33	1·32	1·65

Experiments in Closed Vessels.

Three series of experiments were made, all at the same temperature, viz., 21° C., and with the same proportions of sewage and sea-water, viz., 1 part by volume of the former, and 99 parts of the latter.

In the first series, No. 1 sample of sewage and No. 1 sample of sea-water were employed. In the second series, No. 2 sample of sewage and No. 2 sample of sea-water; and in the third series No. 3 sample of sewage and No. 3 sample of sea-water.

In the following table we give the results of the different determinations—

SEA-WATER AND 1 PER CENT. SEWAGE IN STOPPERED BOTTLES AT 21° C.

Experiment.	Time.	(In cubic centimetres per litre at N. T. P.) Dissolved Gases.				(In parts per 100,000.) Unoxidized Nitrogen as—			Oxidized Nitrogen as—		"Oxygen Absorbed" in 4 hours at 80° F.
		CO_2.	O_2.	N_2.	Total.	Free. NH_3.	Albd. NH_3.	Total.	Nitrates.	Nitrites.	
1	When mixed	45·81	5·23	10·13	61·17	·0171	·0165	·0336	·0066	None.	·144
,,	After 6 hours	46·05	5·20	9·98	61·23	·0171	·0165	·0336	·0062	,,	·126
,,	,, 24 ,,	47·78	3·14	10·03	60·95	·0046	·0263	·0309	·0062	,,	·108
,,	,, 48 ,,	48·91	2·02	10·04	60·97	·0079	·0165	·0244	·0095	,,	·081
2	When mixed	46·74	5·37	10·29	62·40	·0092	·0072	·0164	·0033	,,	·091
,,	After 12 hours	47·18	5·20	10·14	62·52	·0066	·0046	·0112	·0119	,,	·052
,,	,, 18 ,,	46·95	5·08	10·08	62·11	·0079	·0072	·0151	·0058	,,	·059
,,	,, 38 ,,	47·04	4·97	10·11	62·12	·0066	·0059	·0125	·0078	,,	·087
,,	,, 90 ,,	47·18	4·60	9·87	61·65	·0099	·0066	·0165	·0041	,,	·062
,,	,, 528 ,,	47·56	4·42	10·01	61·99	·0138	traces.	·0138	·0062	,,	·069
3	When mixed	46·23	5·30 ?	11·49 ?	63·02	—	—	—	—	—	—
,,	After 7 days	47·31	4·41	11·11	62·83	—	—	—	—	—	—
,,	,, 14 ,,	47·33	3·81	10·60	61·74	—	—	—	—	—	—
,,	,, 21 ,,	47·13	3·87	11·06	62·06	—	—	—	—	—	—

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The most striking feature of this table is the evidence afforded of the great rapidity of the changes which occurred in the first series of experiments compared with those which took place in the second and third series. In the former about 40 per cent. of the dissolved oxygen disappeared in 24 hours, and 60 per cent. in 48 hours, whereas in the second series only about 7 per cent. had disappeared in 38 hours, 14 per cent. in 90 hours, and only 18 per cent. in 528 hours (22 days).

Owing to an accident to the gas analysis apparatus when commencing the third series of experiments, the dissolved oxygen and nitrogen in the original mixture of sewage and sea-water could not be determined; but if it be assumed that the oxygen was about the same as in the preceding series (as was no doubt the case), then, in 7 days (168 hours), only 15 per cent. was lost, and at the end of 21 days, 26 per cent.

The composition of the sewage employed is, no doubt, mainly responsible for this remarkable difference in the behaviour of the mixtures, No. 1 sample being evidently far more concentrated than the other two.

Want of uniformity in the composition of sewage is one of the difficulties which must attend experiments of the kind described, and it is not easy to see how it should be overcome.

It is evident that what is really required is a stock of standard sewage—say, London sewage, but how could this be preserved? If evaporated to dryness, a stock of putrescible substances of uniform composition would, no doubt, be obtained; but they would, of course, have suffered considerable changes during evaporation, and would scarcely be of the same nature as sewage, especially as the characteristic bacteria would have been destroyed.

Another plan would be to experiment, as Dr. Adeney has done, with definite substances, such as urea, asparagine, albumen, etc., and, no doubt, much light would thus be thrown on the subject; but this method would involve an enormous amount of work, as each substance would require separate investigation, both at different temperatures and in different concentrations, and it might after all be urged that such substances do not represent sewage.

Turning, again, to the Table of Results, the evolution of carbonic anhydride—or rather its production—in relation to the oxygen absorbed, presents interesting features. For the sake of convenience we have tabulated them separately—

Series.	Time.	In cubic centimetres per litre.	
		Oxygen Disappearing.	Carbonic Anhydride Evolved.
1	After 6 hours -	0·03	0·24
1	„ 24 „ -	2·09	1·97
1	„ 48 „ -	3·21	3·10
2	„ 12 „ -	0·17	0·44
2	„ 18 „ -	0·29	0·21
2	„ 38 „ -	0·40	0·30
2	„ 90 „ -	0·77	0·44
2	„ 528 „ -	0·95	0·82
3	„ 7 days -	0·89?	1·08
3	„ 14 „ -	1·49	1·10
3	„ 21 „ -	1·43	0·90

It is evident that there is a fairly close agreement between the two sets of figures which is most striking in the case of the first series; and the conclusion seems warranted that, *when sewage decomposes in sea water, the first chemical change which occurs is chiefly the absorption of oxygen and production of almost the equivalent quantity of carbonic anhydride.*

The question naturally arises as to the significance of this reaction. Does it mean that substances of the nature of carbohydrates are first attacked, for example, glucose as the simplest type, according to the equation:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O.$$

or are the nitrogenous bodies attacked with evolution of carbonic anhydride and the formation of more highly oxidized substances? This question can only be decided by experiments on mixtures of substances of definite composition and sea-water; but the first explanation appears the more probable one.[1]

A very instructive result of our determinations is the comparison of the "oxygen absorbed" by the permanganate test with the oxygen actually absorbed as shown by the analyses of the dissolved gases, which clearly show how fallacious the indications of the first-named test are.

This is shown in two ways, and to illustrate the point it will be sufficient to take the figures obtained in Series 1. First, if we take the results obtained from the "oxygen absorbed" test in the original mixture, and contrast it with the oxygen actually absorbed in 48 hours, the figures are, respectively, 0·144 parts by weight per 100,000, and 3·21 c.c. per litre. The latter is equivalent to 4·6 milligrammes per litre, or 0·46 parts by weight per 100,000. In other words, the oxygen actually absorbed was about *three times* as much as the amount shown by the permanganate test.

Next, if we contrast the differences in different periods of the two tests, and translate them into the same units, we obtain the following figures:—

	Dissolved Oxygen actually disappearing after	Differences between "Oxygen absorbed" originally, and after
6 hours -	0·0043	0·018
24 „ -	0·2996	0·036
48 „ -	0·4602	0·063

The figures represent parts per 100,000, and should, of course, correspond if the oxygen of the permanganate acted in the same manner as the dissolved oxygen. This, of course, was not to be expected, but it is surely a remarkable fact that a more energetic oxidation is induced by micro-organisms and free oxygen than by the nascent oxygen of the permanganate solution.

Turning next to the determinations of nitrogen both "unoxidized" and "oxidized," we have, in the Table expressed their amounts in the orthodox manner of parts per 100,000, but owing to the smallness of the quantities involved, and the magnitude of the unavoidable experimental errors, the result may be misleading. In all the determinations (with the exception of the nitrites), the nitrogen was eventually obtained as ammonia, and the latter estimated by Nesslerizing.

In determining both the free and albuminoid ammonia, a modification of the usual process was employed. 500 c.c. of the mixture of sewage and sea-water was distilled until 200 c.c. had passed over into a graduated flask. The contents of the latter were then well shaken, and 50 c.c. Nesslerized for the free ammonia. In a similar manner, after adding the alkaline permanganate, a further 200 c.c. were distilled off, and 50 c.c. Nesslerized as before. It is clear that the results in each case had to be multiplied by 4 to give the free or albuminoid ammonia in the original 500, and by 8 to obtain parts per 100,000.

It is obvious that a small error in the amount of ammonia found in the 50 c.c. of distillate becomes greatly magnified in the expression for the final result. Thus, an error of ½ c.c. of the weak ammonia solution used for the determination corresponds with ·004 parts per 100,000 or ·0033 of nitrogen, and such an error is quite probable.

In the case of the nitrates, the error becomes magnified five times, as 200 c.c. of the original fluid were treated with the zinc-copper couple, and the resulting ammonia determined in the whole of the distillate.

In view of these facts, a more accurate—or, perhaps we should say a less misleading—method of expressing the results would be to give the actual number of cubic centimetres of the weak ammonia solution used in the different determinations, and this we have done in the following table:—

[1] It has been suggested to us that possibly both the absorption of oxygen and evolution of carbonic anhydride may be due to an act on the part of the micro-organisms analogous to ordinary respiration

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Sea-Water and 1 per cent. Sewage in Stoppered Bottles at 21° C.

The number of cubic centimetres of Standard Ammonia solution (1 c.c. = ·01 mg. NH_3) actually required in the different determinations for :—

Experiment.	Time.	$\frac{500}{4}$ = 125 c.c. of mixture. Unoxidised Nitrogen as Free NH_3.	Albd. NH_3.	Total.	200 c.c. of mixture. Oxidised Nitrogen as Nitrates.	125 c.c. of mixture (calculated). Oxidised Nitrogen as Nitrates.	Total Nitrogen.
1	When mixed	2·6	2·5	5·1	1·0	0·62	5.71
„	After 6 hours	2·6	2·5	5·1	1·5	0·94	6·04
„	„ 24 „	0·7	4·0	4·7	1·5	0·94	5·64
„	„ 48 „	1·2	2·5	3·7	2·3	1·44	5·14
2	When mixed	1·4	1·1	2·5	0·8	0·50	3·00
„	After 12 hours	1·0	0·7	1·7	2·9	1·81	3·51
„	„ 18 „	1·2	1·1	2·3	1·4	0·88	3·18
„	„ 38 „	1·0	0·9	1·9	1·9	1·19	3·09
„	„ 90 „	1·5	1·0	2·5	1·0	0·62	3·12
„	„ 528 „	2·1	Traces.	2·1	1·5	0·94	3·04

The table brings out some curious features, which we scarcely like to discuss, as the body of evidence is not sufficient, we think, to warrant us in expressing any very definite conclusions. As a provisional criticism, we may offer the following remarks. The figures corresponding with the total nitrogen are sufficiently uniform to give us some confidence in the others.

As regards these, it would appear that, in the earlier stages of the fermentative process, interchanges occurred between the free and albuminoid ammonia. Thus, in both series of experiments, free ammonia disappeared at the commencement, and afterwards increased. Very possibly the mixture here functioned at first as a Pasteur's solution, the micro-organisms absorbing free ammonia for tissue formation.

In the first series of experiments, there is a fairly steady decrease in unoxidised nitrogen, and a decided, though not so steady, increase in nitrates.

In the second series, the quantities involved are much smaller, and the changes apparently much slower and more difficult to trace in any definite direction.

Experiments in Open Vessels.

The time at our disposal has only been sufficient to perform one series of experiments under fully aerobic conditions, the results of which are given below.

For reasons already mentioned a table is appended of the number of c.c. of weak ammonia solution actually employed in Nesslerizing during the determinations of nitrogen as ammonia, albuminoid ammonia, and nitrates.

The sewage used was (as its examination showed) very dilute, and this possibly accounts for the slow rate of change which its nitrogenous constituents experienced when mixed with sea-water.

As in the case of the experiments in closed vessels, some free ammonia would seem to have disappeared during the first stages of the fermentation, but afterwards the amount increased. Nitrification seems to have set in after about a fortnight.

Sea-Water and 1 per Cent. Sewage in Open Vessels at 21° C.

(Quantities in parts per 100,000.)

Time.	Unoxidized Nitrogen as— Free NH_3.	Albd. NH_3.	Total.	Oxidized Nitrogen as— Nitrites	Nitrates	Total Nitrogen.	Oxygen absorbed. ($KMnO_4$ test at 80° F.)
Original Mixture -	·0112	·0146	·0258	None	—	—	·0780
After 24 hrs. (1 day)	·0072	·0132	·0204	„	·005	·0254	·0823
„ 92 „ (4 days)	·0144	·0132	·0276	„	·005	·0328	·0812
„ 164 „ (7 „)	·0199	·0082	·0281	„	·006	·0341	—
„ 260 „ (11 „)	·0164	·0132	·0296	„	·006	·0356	·0799
„ 428 „ (18 „)	·0168	·0176	·0344	„	·010	·0444	·0762
„ 644 „ (27 „)	·0160	·0160	·0322	„	·012	·0442	·1137
„ 3 months -	·0224	-	—	Some	·004	—	—
„ 7 „ -	·0329	·0164	·0493	„	·070	·1193	—
„ 11 „ -	·0288	-	—	·0028	·080	—	—

The number of cubic centimetres of Standard Ammonia solution (1 c.c.=0·01 mg. NH_3) actually required in the different determinations for :

Time.	$\frac{500}{4}$ = 125 c.c. of Mixture. Unoxidised Nitrogen as Free NH_3.	Albd. NH_3.	Total.	200 c.c. of Mixture. Oxidised Nitrogen as Nitrates.	125 c.c. of Mixture (calculated). Oxidised Nitrogen as Nitrates.	Total Nitrogen.
Original mixture - -	1·7	2·2	3·9	—	—	—
After 24 hours (1 day)	1·1	2·0	3·1	1·2	0·75	3·85
„ 92 „ (4 days)	2·1	2·0	4·1	1·2	0·75	4·85
„ 164 „ (7 „)	3·0	1·2	4·2	1·5	0·94	5·14
„ 260 „ (11 „)	2·5	2·0	4·5	1·5	0·94	5·44
„ 428 „ (18 „)	2·5	2·7	5·2	2·4	1·50	6·70
„ 644 „ (27 „)	2·4	2·4	4·8	3·0	1·88	6·68
„ 3 months - -	3·4	—	—	15·5	9·70	—
„ 7 „ - -	5·0	2·5	7·5	17·0	10·62	18·12
„ 11 „ - -	4·4	—	—	20·0	12·50	—

At the end of twenty-seven days the jar containing the mixture was left at ordinary atmospheric temperatures, and no longer maintained at 21° C. The mixture then contained no nitrites, but the nitrates had increased in amount.

It was not again examined until an interval of about two months had elapsed (*i.e.* three months since the commencement of the experiment), when the nitrates were found to have increased very considerably, and a small quantity of nitrite had also been produced. The mixture was once more examined at the end of seven months, and finally at the end of eleven months.

The results of this series of experiments are, in one way, very puzzling, as the amount of total nitrogen was found to increase as the experiment progressed to an extent which cannot by accounted for by mere errors of experiment.

At first we thought that this increase might be accounted for by the following two causes: first, the room in which the mixture of sewage and sea-water was kept, adjoined a laboratory in which students were at work, and where at times a good deal of ammonia was present in the air; and, secondly, during the long period over which the experiment extended, some evaporation of the mixture of sewage and sea-water must have occurred (although the jar containing it was covered).

But, on the other hand, the increase in nitrogen continued after the vessel containing the mixture had been removed to a room specially reserved for water analysis where no free ammonia could be present in the air (beyond the amount normally found in it), to such an extent as cannot be accounted for by the second cause mentioned. As this investigation is of a preliminary character, further discussion of the matter may be deferred until more experimental data are available. Meanwhile it seems obvious from our experiments that the nitrifying organism can grow in sea-water, and that the changes which occur when putrescible substances are in contact with the latter are probably of the same nature as with fresh water.

The fact, however, that such a large proportion of free ammonia remained unnitrified after so long a period as eleven months is remarkable.

FURTHER EXPERIMENTS ON THE NATURE AND SPEED OF THE CHEMICAL CHANGES WHICH OCCUR IN MIXTURES OF SEWAGE AND SEA WATER.

Some of the bottles from this experiment had remained stoppered and half full of the mixture for 21 months. In addition to clear liquid they contained a white flocky sediment. The contents of two of these were mixed, shaken, and determinations made of free and albuminoid ammonia, nitrates and nitrites, with the following results :—

Sea Water + 1 % Sewage.	Parts per 100,000 of Nitrogen as— Ammonia. Free.	Albd.	Nitrate.	Nitrite.	Total.
Original Mixture - - -	0·0092	0·0072	0·0083	0	0·0197
After 22 days (in full bottles)	0·0138	traces	0·0062	0	0·0200
After 21 months (Aerobic) -	0·0059	0·0133	no trace	0	0·0192

The original nitrate had entirely disappeared, the free ammonia had decreased, but the albuminoid ammonia had nearly doubled in amount.

EXPERIMENTS IN OPEN VESSELS.

As the single series of experiments recorded in the paper had given such remarkable results, two other series are in progress, but under such conditions that no dust can make its way into the vessels, nor can evaporation occur.

In these new experiments pure sea-water from the Irish Channel (obtained midway between Belfast and the Isle of Man through the kindness of D. C. Kemp, Esq., of the Barrow Steam Navigation Company) has been mixed with 1 per cent. sewage in one series, and with 1 per cent. effluent from the experimental bacteria beds at Belfast in the other series of experiments. Neither sewage nor effluent was filtered. The mixtures were made in a large glass jar and syphoned into Winchester quart bottles, each of which was only half filled. The bottles were then stoppered and placed on their sides, pieces of sheet indiarubber having been previously tied over the stopper to keep them in position and to exclude dust. The results of the different determinations up to the present time are given in the following table:—

MIXTURES of SEA WATER with 1 per cent. Sewage and 1 per cent. Effluent.

Experiments at Ordinary Temperatures in Stoppered, Half-filled Bottles; Quantities in parts per 100,000.

Time.	Sewage Mixture.					Effluent Mixture.				
	Nitrogen as—					Nitrogen as—				
	Ammonia.		Nitrite.	Nitrate.	Total.	Ammonia.		Nitrite.	Nitrate.	Total.
	Free.	Albd.				Free.	Albd.			
1. When mixed (Dec. 1900) -	0·0263	0·0148	0·0	0·0051	0·0462	0·0158	0·0092	0·0	0·0165	0·0415
2. After 24 hours (Dec. 21, 1900)	0·0214	0·0231	0·0	—	—	0·0165	0·0115	0·0	—	—
3. ,, 6 days (Dec. 26, 1900)	0·0247	0·0181	0·0	0·0054	0·0482	0·0148	0·0099	0·0	0·0134	0·0381
4. ,, 22 ,, (Jan. 11, 1901)	0·0313	0·0148	0·0	0·0074 ? 0·0033 ?	0·0535 ? 0·0494 ?	0·0181	0·0082	0·0	0·0072 ? 0·0031 ?	0·0335 ? 0·0294 ?
5. ,, 35 ,, (Jan. 24, 1901)	0·0346	0·0123	0·0	0·0020	0·0489	0·0198	0·0082	0·0	0·0092	0·0372
6. ,, 68 ,, (Feb. 26, 1901)	0·0370	0·0133	0·0	0·0016	0·0509	0·0181	0·0076	0·0	0·0062	0·0319
7. ,, 97 ,, (Mar. 27, 1901)	0·0380	0·0123	0·0	0·0025	0·0528	0·0190	0·0066	0·0	0·0092	0·0348

THE SEWAGE MIXTURE.

As in the first series of experiments the free ammonia decreased soon after the mixture was made, and the albuminoid ammonia increased, but after six days the free ammonia had risen, and has continued to rise up to the time of the last determinations. In the same period the albuminoid ammonia has decreased, but not regularly. It increased at first (as already said), then decreased, but has remained stationary for two months. The nitrate has fluctuated, but on the whole decreased during the first two months, while a slight increase has occurred during the third month. So far there has been a slight but continuous *increase* in the total nitrogen as measured by the sum of the free and albuminoid ammonia and the nitrate, this result agreeing with that of the first series of experiments, though it is not so marked.

THE EFFLUENT MIXTURE.

The free ammonia, after decreasing during the first six days, increased from then to the thirty-fifth day. It had again decreased by the sixty-eighth day, but was once more on the increase when last determined.

The albuminoid ammonia, which increased from the time the mixture was made until the sixth day, has steadily decreased since then.

The nitrates decreased on the whole during the first two months, but have increased considerably in the third month.

In this series of experiments there is an apparent *loss* of nitrogen (as measured by the factors already mentioned), which is interesting in view of the fact that in bacteria beds free nitrogen is undoubtedly evolved from the sewage.

CONCLUSIONS FROM THE EXPERIMENTS ON MIXTURES OF SEWAGE AND SEA-WATER.

(1) Under no circumstances is a nuisance likely to arise from sea-water contaminated with sewage up to 1 per cent.

(2) In such a mixture a *rapid action* occurs between the dissolved oxygen of the sea-water and the constituents of the sewage, whereby part of the carbon of the latter is evolved as carbonic anhydride, and, broadly speaking, this latter is equivalent in amount to that of the dissolved oxygen disappearing.

(3) In mixtures of sea-water and 1 per cent. sewage the changes occurring in the nitrogenous constituents of the sewage as measured by the free and albuminoid ammonia and the nitrates are very slow. In no case has the whole of the free ammonia nitrified even after the lapse of an interval of 21 months, on the contrary complete *denitrification* had then occurred.

The fluctuations in the amounts of free ammonia, albuminoid ammonia, and nitrates are very possibly due to the growth of lower forms of plant and animal life, in addition to bacteria.

8575. (*Mr. Power.*) I should like to know as to the proportions of sewage and Lough water where this seaweed grows most luxuriantly. It would vary, of course, with high and low water, but can you give us roughly what the percentage of sewage and seawater was?—I am afraid I cannot; I can ascertain, I think, for you. I should have to consult the Harbour Engineer as to the actual volume of sea water entering a certain section of the Lough with the flood tide, and then I should have to ascertain what would be the amount of sewage which flows from the outfall.

8576. Which flows during all states of the tide, I suppose?—No, with the ebb tide only.

8577. Ebb tide only?—Yes.

8578. Then it is brought back, you consider, with the flood?—So the Harbour Engineer says from float experiments. He gives a diagram. That diagram of mine is a copy of his. I mean to say with regard to the direction of the sewage currents, if you look at the diagram at the end of the paper—the diagram of Belfast Lough—you will see that the currents are indicated by arrows. That was taken from a chart which the Harbour Engineer made as the result of float experiments. His float experiments show that the sewage moves in the direction of the open channel on the ebb tide, but that it never gets very much past a lighthouse which marks the entrance to the channel, for it is caught then by the flood tide and beaten backwards in a bifurcating stream, a portion of the sewage being distributed along the southern shore, and a portion along the northern shore.

8579. Has any observation been made as to the extent over the bottom of the Lough to which this weed extends. Does it grows at all depths do you know? I think, Sir, it is entirely a weed which is found on the shore between the tide marks.

8580. It is washed up at those points, but do you think that it does not extend further to the north-east? It would be growing over the bottom of the

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lough far out, would it not?—I do not think any of it grows on the bottom of the Lough.

8581. You do not think it does; it grows only on the foreshore?—It is only on the foreshore. It is a weed which is confined, I think—virtually confined at all events—to localities which are uncovered at low water.

8582. Indeed?—Virtually; occasionally you may find perhaps a patch which is just a little bit deeper down than that, but I do not think any of it grows in deep water.

8583. (*Mr. Killick.*) Does it generally grow in estuaries, polluted by sewage?—That is just the point which I am very anxious to find out. I think certain conditions are necessary. That is as regards the nature of the shore, slob or sand; certain tidal conditions. I do not think it grows where there is a strong tide, but I am particularly anxious to collect evidence upon that point.

8584. Do you know any other places besides Belfast and Dublin?—When I was at the British Association, as I mentioned just now, there was a gentleman from Cardiff, I think he was Professor Trow, who told me that they suffered in the same way from a nuisance there from the seaweed, but beyond that I do not know. But the nuisance in Belfast is simply appalling.

8585. (*Professor Ramsay.*) Propionic acid has no very disagreeable smell has it?—No, propionic acid is not disagreeable. I think it is the butyric acid which smells.

8586. Yes, that has the smell of rancid butter?—That has the smell of rancid butter; I do not know if you can differentiate the constituents of the smell in the bottle, but you will find the exact smell there.

8587. (*Major-General Carey.*) Are there any sluggish currents in Belfast Lough?—Yes, sir.

8588. Because the sewage apparently only gets out about two miles when it is returned again?—Yes, the currents are very sluggish there—they are less I think than a mile an hour.

8589. (*Professor Ramsay.*) I think there is a natural negative experiment which is made in a lough which is quite near to Belfast Lough?—Yes; Strangford Lough.

8590. Strangford Lough?—Yes, there you have a lough just about of the same area, and which has very much the same surface exposed at low water; I mean large sloblands exposed in the upper reaches of the lough. The chief difference between Strangford Lough and Belfast Lough is that there is no large town near it. In that lough you practically find none of this seaweed. I regard that as rather strong evidence, showing that the presence of the seaweed in a particular locality in quantity—I do not go quite so far as Hartley, but in quantity—is clear evidence of sewage pollution.

8591. Is it possible to utilise the seaweed in any way? It is very nitrogenous; one would imagine it would serve as a manure?—It serves as an excellent manure and especially as a top dressing for grass. The Belfast farmers have discovered that. The North of Ireland people are very shrewd people, they have discovered that, and cart away very large quantities, and put it chiefly on grass; they also use it for other crops.

8592. Does it make a nuisance when it is spread over the ground?—No, the nuisance only arises when it is kept constantly submerged in water.

8593. (*Mr. Killick.*) Have you never made enquiries about either the Mersey or the Dee, where there are such large sloblands left uncovered?—No; but I think the currents there are very strong, are they not?

8594. In parts of the Dee, not the Cheshire side of the Dee?—No, I have not had the opportunity of making inquiries in England as yet.

8595. (*Professor Ramsay.*) Then I suppose it would be possible to take weed off the shore, and stack it or spread it without making a nuisance, and then subequently use it for manure?—Well, I think that might be possible, but it would involve an enormous amount of cartage.

8596. (*Mr. Power.*) Could it be burned on the spot, and the ashes used for commercial purposes in any way?—I do not know for what commercial purposes. I have not determined the quantity of iodine, but I think it will——

8597. (*Professor Ramsay.*) It is pretty sure to be low. Does it dry easily when it is spread on the ground?—Yes, fairly easily.

8598. (*Mr. Power.*) But it remains offensive when passed above high water, although it is not wetted again, did I understand you?—No.

8599. It does require to be constantly wetted with sea water do you think?—It does require to be constantly wetted to become a nuisance, more or less constantly; I mean to say if it is deposited between the tide marks which is really what occurs, then it retains a very large quantity of water itself. It gets wetted with each incoming tide, and then becomes a serious nuisance.

8600. That which is above on the edge of the limit of spring tide very quickly ceases to be offensive do you think?—Yes.

8601. As compared with the other?—Yes, the moment it gets dry. It depends largely on the thickness of the deposits; the very thick deposit might remain, as might be expected, very wet at the bottom for a long period, and then it smells bad, but if it gets distributed to a good height on the bank and in a thin layer it soon dries, and then it ceases to be offensive.

8602. (*Professor Ramsay.*) Do you think that it purifies at all. Is it a purifying agent?—That is just the very point which I am going to try a practical experiment on. Of course the whole question of the sewage disposal of Belfast, in the light of this point about the weed, is a matter of great importance, and the city authorities have entrusted myself and my colleague (Dr. Lorrain Smith, the bacteriologist) with the investigation of the scheme which they propose. The scheme which they propose is merely the ordinary Dibdin bacterial beds, and the question is what will be the effect, so far as the growth of this weed is concerned. Well, this seaweed, from experiments I have made, can only absorb nitrogen from a polluted water in the form either of ammonia or nitrate, so the question is whether the treatment by the Dibdin beds will eventually free the Lough from this seaweed. Now I think it will, for this reason, that the actual amount of nitrogen which disappears in the treatment is so very large. We all know that it amounts to something—I am just speaking roughly, but I think some 60 or 70 per cent. The amount of nitrogen, which disappears in the Dibdin beds is only a fraction of that which reappears in the form of nitrate, so that I hope that by this actual reduction which occurs in the treatment of the sewage, the seaweed will no longer find itself under such nutritive conditions, if I may use the expression, as formerly, and eventually will die out. For there is no question at all that the amount of the weed has steadily increased as the town has grown, and also it has increased since the new scheme was introduced in Belfast for disposing of the sewage by throwing it right out into the Lough. If you look at the chart you will find that now the culvert empties its contents a mile—1½ miles, I think it is, from the outfall, or, rather, from the last pumping station. The sewage runs through this long culvert, and is discharged right out into the Lough. Formerly the sewage of the City was discharged directly into the River Lagan, and that river acted as a settling tank, but now the sewage passes bodily into the Lough. The quantity of seaweed has certainly very much increased since these changes have been made, so that I am in hopes that by removing the greater part of the nitrogen there will be less ammonia, very much less ammonia in the effluent, and that the weed will no longer find suitable conditions for its growth.

8603. Are there any nitrates in the sea water already?—A very minute trace indeed.

8604. And free ammonia?—Free ammonia is very small; I have got some figures here bearing upon that point. In two samples of sea water that I have analysed the free ammonia was the same in both, ·0013 parts per 100,000, nitrate ·0017.

8605. (*Mr. Power.*) What we regard as a good effluent contains a considerable amount of nitrate, therefore I am afraid if the bacteriological process you speak of were effected, it would only give additional nourishment to the weed, would it not?—Well, I have been investigating the experimental filter beds at Belfast, and there is practically no nitrate in the effluent at all.

8606. (*Professor Ramsay.*) From the Dibdin beds?—From the Dibdins; there is a great disappearance of

free ammonia, and practically there is no nitrate produced at all. I have been investigating the cause of that.

8607. (*Mr. Power.*) Double contact beds, are they?—Double contact beds.

8608. (*Professor Ramsay.*) What is the strength of the sewage?—Well, I think it is about—I have not averaged up yet, but about four parts per 100,000.

8609. The total nitrogen?—The total nitrogen about four; it is not very strong sewage.

8610. This is rather new, is it not, to the Commission? I do not think we have ever heard this before, that Dibdin beds cause a disappearance of nitrogen to any great extent without producing nitrates. We know that the nitrogen does disappear, but not to any very great extent?—That has formed the subject of my enquiry lately by a systematic examination of the gases. I mean the dissolved gases. I think I have been able to trace what occurs. My work has not been published yet, but I think I may inform the Commission that in some of the experiments I can account for 20 per cent., at all events, of the total nitrogen which disappears as nitrogen in the free state.

8611. (*Chairman.*) Of what nature is the sewage which goes on to these double contact beds? Is it domestic sewage?—Screened and settled sewage.

8612. But is it domestic sewage or trade effluents?—Oh, there is very little trade effluent in Belfast; I think you may say it is all domestic.

8613. (*Professor Ramsay.*) There are several large distilleries, are there not?—There are several large distilleries, and one of them some time ago was threatened by an action by the Town Council because of the nuisance they caused in the sewer. It so happened that the distillery people engaged me to look into the matter, and I found that the fermentation acids acted upon the ferrous sulphide in the sludge of the sewer, and certainly gave rise to a frightful nuisance. Then the question arose, who was responsible? The city sewer contained ferrous sulphide and the distillery refuse contained butyric acid. The distillery refuse only let loose the nuisance, so to speak. However, the distillery discovered that they could run the whole of their sewage into a river, the Connswater River, and so straight into the Lough, and I am inclined to think they have materially contributed to the growth of this weed as a consequence.

8614. Where does it enter the Lough; could you show us?—I could not show it to you on the plan. It is too small to show, but I could indicate its position roughly.

8615. (*Mr. Power.*) Do you know whether the sewage discharged into the Lough is alkaline in its reaction?—From the tests I have made—I have been examining it through the winter—I find it is perfectly neutral.

8616. (*Mr. Killick.*) Are there any wastes from the linen factories?—Not of any considerable amount. Most of the bleach works are outside the town. There is very little bleaching done in the town of Belfast itself.

8617. Do you think any waste linen fibre, flax fibre, would affect the sewage at all?—I think it would if it were in quantity; I do not think it is in quantity there.

8618. There seems to be a difference between the cotton districts and the woollen districts in England. Possibly sewage from the flax districts in Ireland differ?—I have not gone into that point with sufficient care, but I thought that in the woollen industry it was suint which was the great trouble, the fat in the wool itself, and not the fibre.

8619. Fibre appears to affect the contact beds to some extent?—So I believe, but I do not think that in the linen processes—that is, the spinning and the weaving—that any fibre makes its way into the sewer, because, you see, they are dry processes more or less; they do not involve the use of liquids which pass into the sewer afterwards. It is only the bleaching, and that is done chiefly out of town.

8620. (*Professor Ramsay.*) Is the water which Belfast is supplied with a very soft water?—A fairly soft, peaty water. It contains a very high proportion of albuminoid ammonia.

8621. Do you think it might account for the absence of nitrate in the Dibdin effluent, that there is very little alkali in the water?—I am more inclined to believe that it is caused by the salinity of the water. There is no doubt about it, that a large amount of common salt makes its way into the sewage system of Belfast. I have not as yet traced the sources, but the quantities are exceedingly large. They have varied very much, but quantities like these:—75 parts per 100,000, 54 parts per 100,000, 36 parts per 100,000.

8622. Reckoned as salt?—Reckoned as salt—no chlorine.

8623. Chlorine?—Chlorine.

8624. There is really then about double that amount of salt?—That is really about double that amount of salt, and from experiments which I have made on mixtures of sewage and sea water, and the slowness with which nitrification occurs in some cases, I am inclined to think that the presence of chlorides prevents the formation of nitrates—I am inclined to think so.

8625. Then your idea, taking it as a whole as regards the purification of Belfast Lough, is to starve the seaweed?—As regards the purification of Belfast Lough to starve the seaweed, that is one idea; another idea which I think may be feasible is to keep the seaweed, I was going to say in a tame condition—in a caged condition; that is to say, to have it in tanks, and treat the effluent from the Dibdin beds diluted with sea water in contact with the seaweed for a certain period.

8626. Would you utilise the seaweed?—I would utilise the seaweed.

8627. I mean afterwards as a manure?—If it is possible. Of course you would have to get rid of it in some way, and that would be the simplest way of doing it; but I think, from the extraordinary rapidity with which this seaweed absorbs ammonia—it absorbs all the ammonia from a very polluted water in the course of some 17 hours, a highly polluted water—so that I think the weed might be utilised for purifying the effluent itself or the sewage itself.

8628. Then it is a sort of inoculation experiment. You would inoculate the lough with a small quantity of seaweed so as to avoid the disease?—No; I would pass the sewage through a tank containing the weed, always there until its growth became too extensive, and it would be necessary to clear the tank out. We are actually trying at the works now an experiment of that kind.

8629. Is there any other locality where such seaweed grows—for instance, in Dublin Bay?—I think it might, except that, remember in the case of Dublin, where the seaweed occurs, the sewers are most of them small sewers (*i.e.*, in the northern part of Dublin Bay), and they discharge the whole way down to Clontarf directly on to the shore. Of course they are going to reform that. Now they are going to intercept all the sewage, and, indeed, they are going to chemically treat it, but personally I think that is a great mistake.

8630. Do you happen to know about the sewage of Cork?—No, I do not.

8631. It runs, does it not, into an estuary in very much the same way?—I am not sure whether it runs immediately into the estuary or into the River Lee first.

8632. (*Chairman.*) Do you know of any cases in England at al lsimilar to Belfast?—As I have said, the only case which I know of at all is the one which I think was what Professor Trow mentioned to me at Bradford. I only saw him for a few minutes. It was just after I read the paper, and as I was going, he said to me: "We are suffering from a nuisance at Cardiff."

8633. Cardiff?—Yes, caused by the same thing.

8634. And do they have this seaweed there too?—Well, that is just what I want to find out. I understood from what he said that it was the case, but I have not had time to communicate with him.

8635. And that is the only instance that you know?—That has come under my notice; though there was a friend of mine who is a botanist, and he showed me some letters which he had had from a gentleman at Portland.

8636. At Portland?—At Portland. The sewage ran into—I think it was the sewage from the Convict Prison—ran into a sort of quarry, and the quarry was filled occasionally with sea water, and there this weed had made its appearance in quantity. There can be no question at all about the extraordinary nuisance which is occasioned in Belfast Lough by this seaweed.

8637. (*Professor Ramsay.*) Have you heard of similar

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complaints in Dublin?—No. The area is so very much less which is affected in Dublin; it is only a small area in the northern part of the harbour, and the quantity of weed, so far as I have seen, is nothing like the quantity in Belfast.

8638. (*Mr. Power.*) There is a very small deposit north of Kingstown Harbour. Has there been any complaint of that, do you know?—I do not know. There is a sewage tank which collects all the sewage of that district, and discharges its contents just——

8639. Just where the black spot is?—Yes.

8640. Raw sewage that would be, of course?—Raw sewage, yes.

8641. (*Professor Ramsay.*) Is the seaweed known elsewhere? All round the coast of England a great many seaside resorts discharge their sewage into the sea. Is it within your knowledge that this seaweed has been discovered in the sea of any of these sea ports?—I have found it down at Eastbourne—in fact, adhering to a pipe, and I thought it was the outfall of the Eastbourne sewers. I found the weed there in fair quantity and also on the rocks, and I wrote to the Borough Engineer, and I said: "Is sewage discharged from that pipe?" He wrote back very indignantly, and said: "No, it was not; it was a discharge from some baths." But I think some sewage makes its way down there.

8642. (*Mr. Cotton.*) There is just one question I should like to ask Professor Letts. Is there not another weed—perhaps I am wrong in calling it seaweed—which is very prevalent, and gives rise to a great nuisance? That is the Zostra marina?—There is very little now. Formerly there used to be a very great deal of the Zostra marina.

8643. I remember being there with Mr. Rawlinson, and it was certainly 2ft. deep, and you could smell it a very great deal further than the ulva?—Really there is still a very little of it, but it is practically extinct. I was talking to Mr. R. L. Patterson—I daresay you know him—at all events by name as a local naturalist—and he said it struck him very much the disappearance of the Zostra marina and the appearance of this weed in quantity. There is no question that with the growth and extension of the town, and the disposal of the sewage directly into the Lough instead of into the river, the growth of this weed has increased enormously. In fact, a gentleman living on the shores of the Lough for a great many years said to me: "To show you how much it has increased, in former years when I wanted it for my garden as a manure, I used to have some difficulty in getting a cartload. Now I can get a couple of hundred." So that it has increased very much.

8644. At the time I am talking of—it is a good many years ago now—the weed that was carted in by the farmers was the Zostra marina?—They do not use any of it now. None comes ashore.

8645. I have not been there for some time?—I live on the shore myself, and I will not say exactly daily, but perhaps once a week, I take a walk along to see the condition of the shore, and I have not seen a fibre of it since I have lived there.

8646. (*Professor Ramsay.*) Then your idea is to purify the sewage by the Dibdin process as far as possible, and then, in order to prevent the nuisance occurring in the Lough, to let the sewage through a tank containing this weed. The green weed will deprive the effluent of the albuminoid ammonia and free ammonia which it contains?—Not the albuminoid ammonia. It will not look at it.

8647. The albuminoid ammonia passes on?—The albuminoid ammonia passes on.

8648. It would deprive the weed of the free ammonia which it contains, and of any nitrates which it may happen to contain?—Yes.

8649. And then afterwards the effluent containing albuminoid ammonia would go out into the lough, and it would produce no particular nuisance?—It would produce no particular nuisance. The special experiments I have made with mixtures of sewage and sea water, as regards the chemical changes which occur with such mixtures, shows that the albuminoid ammonia disappears very very slowly, if it disappears at all, after months and months; so no immediate change is likely to occur for weeks, at all events, whereby free ammonia would be liberated.

8650. Now may I ask one or two chemical questions? As regards your methods of determining what is generally called oxygen absorbed: at page 340 of the Royal Dublin Society's Report there is a very interesting point which is mentioned, viz., the dissolved oxygen actually disappearing after six hours, 24 hours, and 48 hours. Certain figures are given, and the difference is between oxygen absorbed originally and after treatment?—Not quite after those periods.

8651. After those periods, yes. I should like to ask as to the method of determining this: was it done at a temperature of 80° Fahrenheit?—Yes; four hours at 80° Fahrenheit.

8652. Four hours 80° Fahrenheit in the usual way?—Yes.

8653. Then you appear to draw a deduction from this that oxygen is removed more readily by bacteria from the water than it is by permanganate?—Well, certainly far more oxygen is absorbed by the bacterial action than by the action of permanganate.

8654. So that bacterial action is a more energetic oxidising process than the permanganate action?—I think so. I think you could clearly say so. That is the greatest feature about it. The point has been criticised by someone else. He said, "Well, the two things are not comparable at all, because in the one case you have only four hours' action, and in the other you have got several days." I do not know whether there is anything in the criticism.

8655. We have been very anxious to know before, and have put questions to experts as to whether the permanganate estimates anything worth estimating?—I am inclined to think not myself.

8656. Is the estimation by permanganate of easily decomposable nitrogenous bodies regarded as important, in your opinion?—I am inclined to think that the permanganate test is used chiefly because it is so easy. As a scientific test I am inclined to think that its results are often misleading. For instance, you might have a considerable quantity of sugar and your permanganate would not discover it for you at all; on the other hand, if you were working with a Leeds sewage, in which I have heard there is a great deal of ferrous sulphate, your permanganate test would give you some remarkable results, I take it.

8657. Occasionally, yes?—Occasionally.

8658. But I do not know that I have made myself quite clear. The permanganate test and the albuminoid ammonia test should ultimately give the same results. The albuminoid ammonia is estimated by means of permanganate?—Yes.

8659. And if one could determine the loss of permanganate in the retort in which the distillation is made one ought to get approximately the same results as by the determination of albuminoid ammonia?—Yes.

8660. Still, the albuminoid ammonia, as a matter of fact, consists of two different classes of substances—one class which goes on fermenting and forming a nuisance ultimately, when the effluent reaches a river, the other class which is comparatively stable, and gives no further trouble, owing to its not fermenting—at all events, which does not give rise to a nuisance after fermentation. The question is—does the permanganate estimate the more or the less stable of these albuminoid bodies or both? Does it discriminate between them in any way? In comparing this permanganate test with the oxygen absorbed test would you be inclined to think that the oxygen absorbed by permanganate discriminates between those two classes of albuminoid bodies?—It is rather difficult to say, I think. If you look at these results on page 337 you will see the disappearance of oxygen is out of all proportion to the changes which occur in the nitrogenous constituents.

8661. Yes?—Indeed, it indicates, I think, what my friend Adeney has called the carbon-fermentation, which is the first phase of fermentation in a putrifying liquid. I mean a putrefying liquid, containing oxygen.

8662. Yes?—The oxygen seems to go at first in oxidising carbon, and not in touching the nitrogenous bodies.

8663. And then subsequently in oxidising the nitrogenous bodies?—Subsequently, but after a very considerable interval, I think.

8664. And in the case of permanganate, would you make any distinction of the same kind? Do you think the instantaneous permanganate test distinguishes the more rapidly oxidisable-carbonaceous bodies, while

the four-hours' test identifies the readily oxidisable albuminous bodies?—I could not say; I should not like to commit myself.

8665. You have no opinion on the subject?—No, I have no opinion on the subject. To tell you the truth, it is the test which, as I say, I have rather a low opinion of. It is a rough-and-ready test, and when it is applied to the same thing under different conditions I daresay it gives indications which are useful. For instance, in the case of a similar series of effluents or a similar set of sewages where you are working under the same conditions, I think that you get some useful information, but as an absolute test I do not believe in it.

8666. And the same remarks would apply to albuminoid ammonia?—Albuminoid ammonia I think more highly of from the experiments which I have made lately with Belfast sewage, where I have compared the albuminoid ammonia with the organic nitrogen. I am rather surprised to find that there is not such a discrepancy as I thought there would be. *Professor B. A. Letts, D.Sc., PH.D.* 7 May 1901.

8667. Have you determined the total nitrogen in the samples mentioned on page 337 in that table?—You mean by the Kjeldahl process?

8668. The Kjeldahl?—No. I found so much difficulty in doing it owing to the large quantity of salt in the sea water. I had to give it up. It spurted all over the place, and there was so much hydrochloric acid going off I was afraid of loss of ammonium chloride, and I had to give it up.

8669. Then have you any idea how to determine the total nitrogen in sea water?—No.

Professor Herdman, of University College, Liverpool, and Honorary Director of Scientific Work to the Lancashire and Western Sea Fisheries Committee, called in; and Examined.

8670. (*Chairman.*) You are Professor Herdman from Liverpool University?—Yes. *Professor Herdman.*

8671. And you have had some experience of sewage and sewage effluents going into tidal waters?—Well, if I may put it this way: For the last 20 years or so I have been studying more or less fish and shell-fish in the sea and in estuaries, and every now and then one has come across the question of the effect upon these of sewage effluents, but it is not the sewage effluents that I have been directly studying, it is the fish.

8672. Possibly you would not mind giving us a general statement of your views on the question?—Yes; well, in the first place may I distinguish between fish, strictly speaking, and shellfish. That is the first point that I would like to make clear. By fish I mean *pisces*, swimming fish; by shellfish I mean the mollusca and the crustacea, and I think the effect is, in some respects, very different upon these two sets of animals. In regard to shellfish beds, edible shellfish, cockles, mussels, oysters, and so on, I think that sewage pollution is wholly bad, and ought certainly to be prevented in every way. In regard to fish, fish proper, *pisces*, it is not at all such an easy matter to give a definite opinion. Different fish are affected in very different ways, and sewage, I think, may be said to act in several different ways upon the fish. Marine fish, I think, are probably not so much affected, not so susceptible as freshwater fish. Flat fish are not so susceptible as what the fishermen call round fish. I mean fish like the plaice, the flukes, the soles, and so on, are not so much affected as fish like cod and the whiting and the gurnard. These are the round fish, that last set. Then again mature fish, adult fish are not so susceptible as young fish. The earlier stages are much more delicate And then amongst these different kinds of fish one can again draw distinctions, if it is necessary. Then I would say further that the sewage, I suppose we may take it, we will all recognise, acts in different ways. First of all it may act through its pathogenic organisms, and any other poisons that it may contain. Then secondly it may act by clogging up the gills of the fish and preventing respiration, affecting the vital processes of the fish in that way. Well, then, these are both direct actions. But you may also have indirect action, because the sewage may form deposits which will prevent the growth of the food of the fish, and so act upon the fishery in an indirect manner. So that you see it is a great deal a more complicated question in regard to the *pisces* than it is in regard to the shellfish beds.

8673. Might I ask if you have ever known of a case of a fish being poisoned by a pathogenic organism?—No, I have no direct evidence in regard to that.

8674. But you would be inclined to think that pathogenic organisms were bad for fish all the same?—Yes; I think if present in quantity they would probably lower the vitality of the fish. I am not prepared to say that they give rise to any distinct lesion in the alimentary canal of the fish, but I should expect that if present in quantity they would lower its vitality.

8675. You have probably known cases where the shellfish have been injurious to human life?—Yes.

8676. In consequence of being impregnated?—Shellfish that were eaten raw.

8677. Yes?—Yes.

8678. But have you ever known a case of fish, other than shellfish, giving rise to disease among human beings?—Well, you see they are not eaten raw.

8679. No?—And the cases that are known of poisoning from eating fish do not, of course, come under the category that you speak of; are probably due to *post-mortem* changes and the development of poisons in the fish.

8680. And have you known any case of a fish being destroyed by the clogging up of its gills?—Yes.

8681. You have?—Oh, yes; I think I have quite good evidence in regard to that in one's own tanks. I may say I have kept many fish in tanks at several different biological stations for many years, not with the object of investigating sewage specially, still I have had them under various conditions with various kinds of impurities in the water, and amongst other things I have tried quantities of fine silt, and such materials do injuriously affect the gills of the fish. And then I have had dead fish sent to me where one has found the gills very much clogged up with fine material. I did not doubt that in such cases it was either the, or a, cause of death. It may have acted along with other influences.

8682. Have you found that both with sea and river fish?—Mainly sea, but I think I have had river fish also. I think I have had fish sent to me in that condition from the Dee in the neighbourhood of Chester. I am speaking from recollection now, because it was marine fish that I came to speak about and that I know best, but I am inclined to think I have had freshwater fish sent me from the Dee.

8683. Then to clog the gills up, would the water or the liquid in which they were have to be very thick?—Yes.

8684. Very thick indeed?—Oh, yes; very thick. I do not know whether you would like me to state now anything further that I have to state.

8685. Yes, anything that you please, please do?—Well, I wanted to say after what I had said in regard to the way in which sewage might act upon the fish, that on the other hand I think it would be unfair not to state that sewage may act as a food. I do not think that perfectly fresh sewage under all circumstances is injurious. I have had many cases in which I have kept fish alive for lengthy periods in tanks with sewage. I have added fresh sewage matter without allowing it to decompose; I mean I have renewed the water in the tank and renewed the supply of sewage in the water periodically; have kept it well aerated; and under such conditions some shellfish will live apparently indefinitely. Certainly over weeks apparently without deteriorating in the least, and they will eat the sewage. But then again there is no doubt at all that some of the other animals that are not, strictly speaking, fish, not *pisces*, feed upon sewage. Shellfish certainly feed upon sewage; shrimps feed upon sewage; many of the minuter things which form the food of the larger ones feed upon the sewage; such as the little animals in the sea called *Copepoda*, small crustacea, microscopic things which are present in enormous amount, which are probably more important than anything else in the sea as the food of fishes. They feed largely on sewage, and act really as scavengers, and convert sewage largely into what one may call good food for the fish. I know a place on the Lancashire coast, off Blackpool, where the sewage is apparently carried out by

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the ebbing tide, along a definite area, and where there are great banks of shellfish, not edible shellfish, which in their turn are eaten by such fish as the plaice. The shellfish I speak of are such as *mactra* and *scrobicularia* and others, and I have no doubt that they are there because of the sewage. They are nourished, and then they form a very good feeding ground for the flat fish. So that there is this side of the matter to be considered as well as the other.

8686. (*Professor Ramsay.*) Might I ask in passing whether flat fish eat the shells as a whole?—They do.

8687. Swallow everything?—Swallow everything. If you cut up the flat fish you find the shell in a comminuted state in their stomach. That was the other point I wished to lay before the Commission.

8688. (*Mr. Killick.*) In speaking of sewage and its effect upon fish, you speak, I suppose, of domestic sewage?—Yes, where I have used it experimentally as in these tanks at biological stations. I have sometimes merely taken it from the mouth of the drains, as, for example, that is what I have done at Port Erin in the Isle of Man, where I have a biological station. In other cases I have merely made it up from small quantities of human fœcal matter, of horse dung and urine, so that would be what you mean by domestic sewage.

8689. You have not made any observations where there have been trade effluents in the tank?—No. .

8690. You said, I think, that sewage is less dangerous to fish life when turned into the open sea than it is when turned into a river?—Yes; for two reasons; first of all, because I think it very soon in the sea becomes mixed with such an enormous volume of water that it must in a very short time be very dilute. Then, in the second place, I am under the impression that it is more aerated in the sea, and aeration has, I think, a more important effect than anything else upon the life of fish. I mean that I have kept fish in water that really was very much polluted and very thick, indefinitely, for weeks, so long as one kept that water thoroughly aerated, aerated it several times a day, while other tanks—control tanks—which were under the same conditions, but were not aerated, proved fatal to life—fish-life of all kinds—very soon. And in other tanks where the water was very much purer, almost no sewage matter, or none at all, if you allow them to stagnate, if you do not aërate them, the fish very soon die; so that I would lay very great stress upon the thorough mixing up of the sewage, such as happens where there is a tide—where the water is thoroughly aerated.

8691. But if the tide returns the sewage to a mud-bank, then the risk would be very great; if it throws it back on to the shore?—The risk, you mean, of forming a deposit such as would interfere with life on that mud bank?

8692. Yes?—Yes, that is what I alluded to as the indirect action, where the food of the fish is killed off in considerable areas, by deposits of sewage-mud forming.

8693. The danger to health from eating raw fish, would it come from eating the fish or from swallowing the water contained in the shells?—Both; the water contained in the shells contains the organisms, contains numbers of organisms; so does the alimentary canal of the shellfish, which, of course, runs through its body, and you cannot help swallowing that, even if you wash the exterior. If you wash out the mantle cavity, the cavity between the pallial folds, you still leave the alimentary canal of the animal, which contains organisms. . .

8694. Even though you get rid of all the water in the shell, the oyster or mussel, or whatever it is, may be poisonous?—It may be, but you get rid of a good deal of the chance if you get rid of the water. .In some experiments Professor Boyce and I made some years ago, in regard to oysters, we found that there were more organisms on the outside than in the inside, so that you get rid of a large proportion of the risk in cleansing the outside, but still you do leave some risk, because of there being the alimentary canal, the food canal of the animal, running through its interior, and that, of course, may contain anything that was outside the animal.

8695. (*Major-General Carey.*) Is it your opinion that a sewage effluent which passes over oyster beds, or shellfish of any kind, should be treated beforehand, and should undergo some process of purification before the discharge takes place?—If that purification is effectual, certainly; but I understand—this is not from my own knowledge—but I understand that such treatment does not destroy the pathogenic organisms, and leaves the effluent—even though it may look very difficult from crude sewage—leaves it really with as many organisms as before. In that case, of course—from the public health point of view—it is no use.

8696. Under those circumstances it does not matter whether the sewage is treated or not?—So far as pathogenic organisms are concerned.

8697. Does a fish feed on decomposing sewage?—Some fish do. I have seen fish do so. I will not say that all fish do; some do; and some shellfish; and shrimps, certainly.

8698. What would be the effect in salmon rivers of the fish feeding either on fresh or on decomposing sewage?—Well, I do not know anything about the salmon feeding on sewage. I am talking of marine fish.

8699. (*Professor Ramsay.*) Do salmon feed at all when in a river?—That is disputed; I mean we have had a good deal of scientific evidence of late years that they do not feed at all; but, of course, some other people say they do.

8700. I have seen large trout feeding at an outfall?—I have seen exactly the same thing in regard to marine fish, and of course it is well known that shellfish grow much larger round the mouths of sewers. We caught a boy the other day up a drain near Egremont, in the Mersey, collecting mussels to sell, and he went there because they were larger than he could get anywhere else.

8701. To eat; not for bait?—No; to eat; to sell in the market for food; he went up the inside of the drain for them.

8702. (*Major-General Carey.*) What would be the effect on trout of crude sewage being turned into a trout stream?—I do not think I can give you any useful opinion about that. It would largely depend on the amount of it, and how readily it was carried away, whether it was allowed to decompose, and whether the water was thoroughly aërated.

8703. (*Professor Ramsay.*) I suppose there can be no doubt that whether or not fish are injuriously affected—when I say fish, I mean shell-fish, as well as vertebrate fish—whether or not fish are injuriously affected by sewage, it is possible for human beings to get disease by eating them?—By eating the shellfish?

8704. By eating the shellfish?—Yes.

8705. That has been indisputably proved?—Oh, I think so; I consider it so.

8706. Can the same fact be alleged of vertebrate fish?—I do not think so. You mean after the fish has been boiled—after the fish has been cooked.

8707. Yes. Well, of course, raw fish are not eaten?—Raw fish are not eaten, and I think if fish is sufficiently cooked it would destroy the organisms.

8708. The organisms would be destroyed?—Yes.

8709. Can you give us any idea of the amount of oxygenation in the water necessary for the life of *pisces*?—No; no I cannot tell you in figures at present. I think it is known; I think it is in the books, but I have not got it with me.

8710. Is there any difference in the amount required for shell-fish?—No, I do not think so.

8711. They would be affected at the same time?—They would be affected, but the exact amount of effect would depend upon the habits and activity of the animal.

8712. I will give you a concrete case: In summer—in July, for example—the Thames very often contains extremely little free oxygen. Not merely fish might be killed by this absence of oxygen, but also their food; is that possible?—It is so.

8713. Would it be possible to find out what amount of oxygenation of a stream makes it perfectly impossible for fish to exist?—I think so.

8714. Of course, that is one of the first points, when we consider the effect of sewage in a stream, whether the effluent, from sewage treatment, deprives the stream of oxygen?—Of oxygen, quite so.

8715. And may reduce it, under unfavourable circumstances, below the limit?—Quite so. That is why I lay stress on the aeration of the water; the thorough mixing up and taking up of fresh air by the water such as happens in the sea.

8716. Yes, quite so. Is there any evidence of the production of ptomaines from the sewage when a bad effluent is run into an estuary or into a river?—Well, that is outside my own province, but I think there is. Is it not known that there is?

8717. I do not know that there is?—I am inclined to think there is, but that is outside my own knowledge.

8718. Has the effect of ptomaines upon fish at all been investigated as regards their health?—No. What I was thinking of was this: Of course there have been investigations as to the production of ptomaines in the fish affecting human health, but that is another question.

8719. That is another question?—Affecting the health of the fish. No, I do not think there has been any investigation—at least none that I know of.

8720. I know that the effect of a considerable number of poisons has been investigated on fish, has it not?—What kind of poisons?

8721. Such as arsenic, for example?—Oh, yes. Yes, and such poisons as are contained, you mean, in chemical effluents?

8722. Chemical effluents?—Chloride of lime.

8723. Chloride of lime?—Caustic soda, sulphurous acid, mercuric chloride, copper and iron salts, and so on.

8724. These have been investigated?—Yes; that is the case. I know of such cases in my own tanks.

8725. Do you know where the data is to be found?—I could lay my hand on them easily. I have seen papers. I cannot tell you now.

8726. Then as regards the clogging of the gills of the fish. Do you think that is likely to take place owing to what one may call colloidal matter in suspension, albuminoid substances, or, perhaps, flocks of hydroxide of iron? Is that the sort of thing that clogs the gills?—Yes.

8727. The gills are rough, are they not?—Minutely rough.

8728. One would feel them somewhat rough to the touch on the exterior?—Yes.

8729. They are full of points?—Yes.

8730. They would attach themselves to the colloidal matter?—That is the case.

8731. And it is not easy to get off? It does not wash away?—It does not wash away. It is very difficult to get off even with a camel's-hair brush, to give you an instance.

8732. That hinders the oxygen passing into the gills?—Yes.

8733. Is that a frequent cause of death of fish, do you think?—No, I do not think I should call it frequent. No, I think it is only under unusual conditions, such as laboratory conditions, when we are making experiments, or in the few cases I have mentioned where fish has been sent to me in that condition, and these have been very suspicious. I should say it was not at all frequent with fish in the sea.

8734. Have you had any experience at all with fish kept in bacteria bed effluents?—No.

8735. There are frequently carp and gold fish kept in such effluents?—Yes

8736. You have not examined them?—No. I have kept gold fish myself in tanks with a great deal of sewage matter, and I find they are exceedingly healthy.

8737. Do not their gills tend to clog, or have you not examined them in that way?—I have not noticed it. I have not had any that died obviously from that cause.

8738. The reason I am putting all these questions is that in certain processes of sewage purification a very considerable amount of colloidal matter is produced. The question is, if that organic matter gets into the streams, whether it would be prejudicial to the fish?—Yes.

8739. Or even inorganic matter, because collodial matter may be inorganic?—Yes.

8740. It is a question as to whether it should be removed from the effluent or not before it is allowed to reach the stream. You think it would be safer, at all events, to remove it?—Very much safer to remove it, yes.

8741. You mentioned in your statement that fish are not injured by fresh sewage. Do you intend to lay any emphasis on the word "fresh"?—I meant before it decomposed. That is what I meant—that it did not putrefy.

8742. But have you had any evidence that it does putrefy?—Only the evidence of having kept them in tanks over and over again, and I have found that it makes a very great difference. As I think I stated, I have kept tanks going in which I renewed the water and put in fresh sewage day by day, and have kept other tanks in which I allowed the old sewage to remain and decompose, and I found that these two circumstances acted very differently.

8743. Does the fish's own excreta injure it?—Oh, I do not think so.

8744. Too small a quantity?—Too small a quantity. I do not think that affects the question.

8745. If you were to run some septic tank liquor into a fish tank, and kept up the aeration, you do not think the fish would be affected?—I do not think they would be affected—no, I lay very great stress upon aeration.

8746. Can you say whether any typhoid or any other disease which is communicated by oysters has ever been communicated where oysters were grown near an effluent which was good chemically, or has it always been where the crude sewage was run into the sea?—I think the cases that I have known of have all been cases of crude sewage—just from a drain, from an ordinary untreated drain.

8747. How do you think that oyster beds ought to be protected so as to avoid contamination in this way?—Oh, I think the oysters ought to be kept away from the drains.

8748. Away from them entirely?—Away from them entirely.

8749. (*Major-General Carey.*) Is that possible?—Well, then, put the oyster bed away from the sewer.

8750. (*Professor Ramsay.*) The question is how far away. Is the contamination likely to reach far?—Well, it will reach further, of course, in an estuary than in the sea. You will have to study each particular case—see what the set of the tides is, and the current in the water. I mean, under some circumstances contamination might reach a long distance because of the current. In other cases it might be mixed so soon with a large volume of sea water as to be innocuous.

8751. About crustacea: When they breathe, are their breathing organisms the least likely to become clogged in the same way as fishes do?—No. Their gills are so different. They are absolutely smooth, and are covered with a thin layer of chitin like part of the rest of the exo-skeleton of the animal. Whether that is the reason or not, as a matter of fact I do not think you would find a crustacean with its gills clogged.

8752. And I suppose the same would be said *a fortiori* of shell fish?—No. Shell fish are very different. They have ciliated gills—quite different they are—and ciliated gills are liable to become clogged. I have seen the gills of mussels badly clogged.

8753. And if an immense amount of sewage was turned out of a bed that would naturally put an end to the shell fish?—You very often find shell fish put an end to not merely by sewage, but by mud. It is exceedingly bad for an oyster bed or a mussel bed to have mud collect, or if a sandy region with a cockle bed becomes too muddy because of some change in the deposit, then the cockles will die out.

8754. (*Chairman.*) Have you ever known the shell fish themselves suffer from pathogenic organisms?—No. Professor Boyce and I, when we were working at the oyster a few years ago, tried to get evidence with regard to that, in regard to the oyster, but we could not find any lesion in the animal's own tissues.

8755. Then, taking the case of an oyster bed where the pathogenic organisms were numerous, the shell fish would be so much affected that they would be dangerous to the health of human beings, but in the neighbourhood of that same oyster bed would all sorts of fish be able to live, do you suppose, or would the pathogenic organisms hurt any kind of vertebrate fish?—Oh, I think the fish would be able to live. If it was a place where the oysters would be able to live, fishes would be able to live.

8756. Then you might have infected waters that would be quite innocuous to fish, but which would be dangerous to human beings if they ate raw shell fish coming from them?—Yes.

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8757. Then human beings and fish are not at all in the same boat?—No.

8758. (*Professor Ramsay.*) Would putrefiable suspended matter have any influence on the life of fish of any kind? The object, of course, of these processes is to turn out an effluent which will not further putrefy, but it is not always successful.—Well, if it contains putrefiable material, that will certainly use up oxygen, will it not?

8759. Oh, yes?—And in that way alone it would have a prejudicial effect, or might have. I do not quite see at the moment the need of any other.

8760. Dr. Houston suggests that the humus which is the general product in effluents, which is not putrefiable, might form deposits?—On the bottom, you mean.

8761. On the bottom; of course, that would not interfere with vertebrate fish?—It might interfere with their food. For example, a very great part of the food of some of our most esteemed fishes, the flat fishes, consists of marine worms and shellfish, molluscs. They are not edible ones; they are smaller shellfish than cockles and mussels. Well, now these animals require a fairly open bottom. They require sand or shells, zoophytes, and suchlike, and wherever there is a deposit of fine mud of any kind it will interfere with the life of these animals which are the food of fish. Also, anything that in shallower water would prevent the growth of seaweeds will still more in an indirect way affect the life of fish, because the invertebrates feed upon the seaweeds.

8762. Perhaps I might just put a general question: Water free from chemicals and from putrescible suspended matter in general you do not think would be injurious to fish?—If it were free from chemicals and putrescible matter.

8763. So that we may take it that any constituent of an effluent which has not much effect on the oxygenation would not be injurious to vertebrate fish life.—Quite so, I think.

8764. To vertebrate fish life?—Quite so. I think that is my general opinion.

(*Mr. Killick.*) That is directly, of course.

8765. (*Professor Ramsay.*) Directly?—Yes. I brought with me some laboratory notes here of experiments made comparatively recently, but they are just on the same lines as many others I have made before. I think I have given you the results in general terms without going into each particular experiment. There is just perhaps one other remark I would make that I see in comparing two of those sheets, and that is, that I have some evidence that the fish that I experimented with over at Port Erin in the Isle of Man, where the water is exceedingly pure, were more susceptible to sewage than the fish that I experimented with at Liverpool, which were caught in the estuary, and which, from the fact of their being shore fish, have probably all their lives been in the estuary; so that I have no doubt there is a certain amount of acclimatisation goes on, and the fish in the estuary are able to stand more than the same kind of fish elsewhere: because it was the same kind of fish in both cases.

8766. Have you any definite experience as regards the action of metallic poisons?—No.

THIRTY-SECOND DAY.

Wednesday, 8th May, 1901.

PRESENT:

The Right Hon. The Earl of IDDESLEIGH (*Chairman*), *presiding.*

Sir MICHAEL FOSTER, K.C.B., F.R.S., M.P.
Mr. WILLIAM HENRY POWER, F.R.S.
Professor WILLIAM RAMSAY, F.R.S.
Major-General CONSTANTINE PHIPPS CAREY, R.E.
Mr. THOMAS WILLIAM KILLICK.
Dr. JAMES BURN RUSSELL.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS, *Secretary.*

PRESENT ALSO:

Dr. G. McGOWAN. | Dr. A. C. HOUSTON.

The Hon. THOMAS HENRY WILLIAM PELHAM, Assistant-Secretary to the Board of Trade, Fisheries and Harbour Department, called in; and Examined.

Hon. T. H. W. Pelham. 8 May 1901.

8767. (*Chairman.*) You are an Assistant Secretary to the Board of Trade in charge of the Fisheries and Harbours Department?—Yes.

8768. And you are good enough to come here to give us the views of the Board of Trade on the subject of the discharge of sewage and sewage effluents into tidal waters?—Yes.

8769. Perhaps you will give us a general statement of your views?—I have been directed by the Board of Trade to attend before the Commission in consequence of a request from the Chairman of the Commissioners that the Board would appoint one or more of their officers to lay before the Commission the views of the Board in regard to certain questions connected with the discharge of sewage into tidal rivers, estuaries, and the sea.

It is necessary that I should say at once that I am not able to offer any evidence as to the effect of crude or other sewage on different kinds of fish, or as to what degree of purification is necessary to render sewage innocuous. This is a question involving prolonged chemical and bacteriological investigations which the Board of Trade have never been put in a position to conduct. I am only able to give the Commission information as to what powers the Board of Trade possess with respect to the discharge of sewage, and as to the complaints which have from time to time been made as to the injurious effect of such discharge.

The Fisheries Department of the Board of Trade was constituted in 1886, and in the inspectors' reports of 1887 attention was called to the pollution of rivers as a serious impediment to the production of fish, but these reports had reference principally to the upper waters of the rivers, and it was not until 1888 that the Board of Trade began to take serious action with regard to the pollution of tidal waters as affecting fisheries. Local Sea Fishery Committees were established under the Sea Fisheries Regulation Act, 1888, and under Section 2 of that Act local Committees obtained power to make bye-laws for the following (amongst other purposes):—

> "(e) For prohibiting or regulating the deposit or discharge of any solid or liquid substance detrimental to sea fish or sea fishing."

The following are specimens of bye-laws which have been made under this clause:—

PROHIBITION OF DEPOSIT OF REFUSE.

Specimen Bye-laws.

Kent and Essex District (Confirmed 1895).

15. The deposit or discharge of any solid or liquid substance detrimental to sea fish or sea fishing is hereby prohibited. Provided that this bye-law shall not apply—(1) to the deposit or discharge of refuse by the Lords Commissioners of the Admiralty in the River Thames below "The Mouse" lightship and near the "Mouse Sand," or (2) to the deposit by any other person with the consent in writing of the Committee, given under the hand of their clerk, and confirmed by the Board of Trade, of any such solid or liquid substance on an area shown on a chart referred to in the consent, and in accordance with the conditions laid down in that consent. Any person acting in contravention of this bye-law shall on summary conviction be liable for each offence to a penalty not exceeding £20, and in the case of a continuing offence the additional sum of £10 for every day during which the offence continues.

A similar bye-law is in force

(1) With exempted areas or power to exempt areas—in Sussex, Southern Milford, Lancashire and Western Cumberland Districts.

(2) Without affording power to exempt areas—in Eastern Suffolk and Essex, Frome, Southampton, Teign, Camel, Glamorgan, Dee Districts.

Devon ; Kent, Bela, etc.

2. The deposit or discharge of any solid or liquid substance detrimental to sea fish or sea fishing is hereby prohibited [provided that nothing in this bye-law contained shall affect the power of any sanitary or other local authority to discharge sewage in pursuance of any power given by a general or local Act of Parliament or by a Provisional Order confirmed by Parliament, or from any outfall in use at the date of the confirmation hereof].

[This is an early form of bye-law. The proviso is not now inserted, as the point is met by Section 13 of the Act. See below*.]

COLCHESTER HARBOUR.

Certificate dated 26th May, 1891.

No person shall deposit or discharge any earth, gravel, ashes, manure, rubbish, refuse, sludge, filth, or any other solid or liquid substance whatsoever detrimental to sea fish or sea fishing in or into any part of so much of the area of the Harbour Jurisdiction of the Town Council of the Borough of Colchester as is not included within the Kent and Essex Sea Fisheries District. (*Here follows penalty.*)

These bye-laws have no validity until confirmed by the Board of Trade.

In 1888, and again in 1892, attention was called to the deposit of rubbish in the estuary of the Thames, and as a result of an inquiry held by Mr. Fryer and Captain Tizard, R.N., by direction of the Admiralty in the latter year, the deposit was transferred to the Barrow Deep.

At the annual conference of representatives of Sea Fisheries Committees in 1896 it was pointed out, in connection with complaints of deposits from manure barges in the Thames estuary and on the Essex coast, that prosecutions (one at Sheerness and the other at Colchester) had failed on account of the difficulty in proving that such deposits were detrimental to fish.

Neither the Sea Fisheries Acts nor the Salmon Fishery Acts give the Board of Trade any direct power to prevent the pollution of the sea or tidal waters by the discharge of sewage except that, as already pointed out, bye-laws made by Sea Fisheries Committees have to be confirmed by the Department.

The Board of Trade, however, have an indirect control over the discharge of sewage, inasmuch as no works can be constructed on the foreshore or the bed of the sea without their consent.

By the Crown Lands Act, 1866, 29 and 30 Vict., c. 62, S. 7, the rights and interests of the Crown "of and in the shore and bed of the sea and of every channel, creek, bay, estuary, and of every navigable river of the United Kingdom as far up the same as the tide flows" were transferred from the management of the Commissioners of Woods to the management of the Board of Trade. This section vests in the Board of Trade a very large portion of the foreshore of the United Kingdom, but not the whole, for, by other sections of the Act, a considerable portion is reserved to the Commissioners of Woods, and in Lancashire and Cornwall the foreshore belongs to the Duchy of Lancaster and the Duchy of Cornwall respectively. In some other parts of England the foreshore has by grant or prescription become vested in private owners. The extent of private ownership is not known.

In places where the management of the foreshore is not vested in the Board of Trade their consent is still necessary to works on such foreshore on the ground of interference with navigation, the jurisdiction of the Admiralty in these waters having been transferred to the Board of Trade by the Harbours Transfer Act, 1862 (25 and 26 Vict., c. 69).

Oysters and Shellfish.

The Board of Trade have not received many complaints of pollution of oysters or other shell fish by the discharge of sewage. Those interested in the fisheries would naturally be unwilling to call attention to their fish being exposed to infection.

In 1892 the Board received representations from the Bosham fishermen with reference to a proposed sewage scheme for Chichester. In connection therewith I produce a letter addressed by the Board of Trade to the Local Government Board in 1893, calling attention to certain cases of injury to health and life supposed to be due to the eating of shell fish exposed to contamination by sewage. This letter refers to cases at Ramsgate, Margate, and Dublin, and also to a case in Germany. Exhibit 1.

In 1896 a resident at Emsworth complained of pollution of oysters by sewage, but the Urban District Council denied that any danger existed. In the same year the Cowpen Urban District Council suggested that a mussel bed in the River Blyth should be removed from the vicinity of a sewage outfall. The Board of Trade replied that they had no power to take such action, and that the better course would be to divert the sewage. In 1897 the Southampton Local Fisheries Committee forwarded a complaint as to deposit of oysters in a sewage-infected pond, and were referred to the sanitary authority, and a somewhat similar complaint was received this year from the Corporation of Falmouth.

The Board of Trade, therefore, have no special information as to the damage caused by the pollution of oysters and shell-fish beds except such as are contained in the reports of officers of the Local Government Board.

Between the years 1894 and 1899 public attention was called to cases of typhoid fever which was attributed to the consumption of oysters contaminated by sewage, and in the latter year a Bill introduced into Parliament on behalf of the Local Government Board was strongly opposed by some of the representatives of the fishery interests on the ground that while it imposed serious restrictions on the sale of oysters, nothing was proposed to be done to prevent the discharge of sewage into tidal waters by local authorities.

In May, 1900, a promise was made on behalf of the Board of Trade that in future cases of application to the Board for consent to the construction of sewer outfalls upon the foreshore an opportunity would be afforded to local sea fisheries committees of showing cause against the grant of such consent.

Several cases in which the interests of fisheries were likely to be prejudicially affected had already been dealt with by the Board of Trade, and since May, 1900, about twenty instances have occurred in which the Board have withheld their consent to works on the foreshore or tidal lands until some steps were taken to secure as far as practicable the purification of the effluent or otherwise to reduce the possibility of serious contamination of the water. This policy has been adopted both as regards the tidal parts of the river and as regards the sea coast (including estuaries), except that in the case of the sea coast the Board have raised no question as to the discharge of even crude sewage unless the point of discharge was in the neighbourhood of oyster or other shell-fish beds. Exhibit

The principal ground of complaint with regard to oysters is not that the fish are destroyed or injured by the discharge of sewage, but that as they are some-

* Section 13 of the Sea Fisheries Regulation Act, 1888, provides as follows:—

"Nothing in this Act shall authorise a local fisheries committee to make any bye-law—

(*c*) affecting any power of a sanitary or other local authority to discharge sewage in pursuance of any power given by a general or local Act of Parliament, or by a Provisional Order confirmed by Parliament."

Hon. T. H. W. Pelham.
8 May 1901.

times eaten raw, the consumer may swallow with or in the oyster the contaminated water. The same danger exists in the case of mussels and cockles, which are sometimes eaten raw.

So far as regards the danger to human health, the matter is one which principally concerns the Local Government Board or the local sanitary authorities.

Exhibit 3.

The Board of Trade are bound, however, to consider the damage which is likely to be caused to the fishing interest when a case of typhoid fever is attributed to oysters. In such a case all oysters, whatever their origin, are more or less laid under suspicion. The Board of Trade's view, therefore, is that measures should be taken to prevent the contamination of the oyster beds rather than to place restrictions on the sale of oysters after they have been contaminated, though, of course, these restrictions may be necessary where the oysters are actually contaminated.

I have already stated that it has been represented that prosecutions against bargeowners for depositing manure in the Thames estuary in contravention of bye-laws under the Act of 1888 have failed in consequence of the difficulty in proving that such deposits were detrimental to fish. It is anticipated that there would be greater difficulty in enforcing bye-laws as to the discharge of sewage near oyster beds, more especially where the discharge is from an outfall which has been sanctioned by the Board of Trade either as owners (for the Crown) of the foreshore, or as guardians of navigation.

Exhibit 4.

The only way, therefore, in which the Board of Trade can take measures for preventing contamination is by withholding their consent to the construction of outfall sewers in the neighbourhood of oyster beds. There are several difficulties in this mode of procedure. In the first place, there are many places where the foreshore is not under the management of the Board of Trade, and it is difficult to make the interests of fisheries a ground for objection when the power of the Board of Trade is devolved upon them from the point of view of navigation only. Another difficulty arises when the local conditions are such that if there

Exhibit 5.

is a marine outfall it must be somewhere near the oyster beds, and the only safeguards which can be taken are by imposing conditions: (1) as to the purification of the effluent; (2) as to the hours during which the discharge may be taking place; (3) as to the inspection of the works; (4) as to future modification of the scheme in the case of increase of volume of sewage to be discharged, or in the event of fresh means being discovered for rendering the effluent innocuous. The Board of Trade have in certain cases attached conditions of this nature to their consent to the construction of outfall works; but they are not easy either to impose or to carry out as the law stands at present.

As regards the purification of the effluent, the Board of Trade have not attempted to form any opinion as to the efficiency (in relation to shell-fish) of the different systems which have been adopted. Whether or not the effluent discharged under a particular system would be injurious to persons eating raw oysters or shell-fish gathered from the neighbourhood of the outfall is a question upon which they have always hesitated to express an opinion or give a decision. They are prepared to be guided in this matter by the Local Government Board in cases where that Department can assure the Board of Trade that the effluent will be sufficiently purified, so as to remove the probability of the oyster beds being infected. But they consider that the consent of the Board of Trade should be rendered necessary to any outfall sewers on the sea coast or in the estuaries of rivers in the interests of fisheries, whether or not the foreshore is vested in the Board of Trade; and, further, that the Board should be empowered to attach conditions to such consent, and to enforce compliance with those conditions.

Salmon Fisheries.

The injury caused to salmon fisheries by the discharge of sewage into tidal rivers is of a somewhat different nature from that caused to oysters and shell fish. The danger is to the fish themselves, and not to the persons who consume them.

Some years ago the Home Office made representations to the Local Government Board on this point, with the result that that Board undertook to require special measures to be taken for the purification of sewage before the discharge of any effluent into the estuaries of salmon rivers, and the Board of Trade have from time to time called the attention of the Local Government Board to cases in which the interests of the salmon fisheries were likely to be or were being affected by sewage discharge, whether into tidal or inland waters. I hand in a list of specimen cases in which representations have been made to the Local Government Board.

Exhibit 3.

The Board have in certain cases withheld their sanction to the construction of outfalls on the foreshore of tidal rivers, in order that they may obtain a guarantee somewhat similar to that already described with respect to outfalls near oyster beds. The difficulty of enforcing conditions of this nature is very great where crude sewage is already discharged into another and possibly a not distant part of the river. An authority objects, and with some force, to a refusal of permission to do that which its neighbour is already doing. If the salmon, they say, survive the operations of the sanitary authority below or above, ours will not kill them.

With regard to facts as to cases in which actual damage has been done to salmon by the pollution of rivers, the Board of Trade have only information at second hand from the Boards of Conservators, by whom the cases are usually dealt with without reference to the Department.

The annual reports of the inspectors of fisheries show that complaints in general terms of the pollution of rivers have been received from the Boards of Salmon Conservators. The great majority of these complaints, however, refer to non-tidal waters, but I have in my hand a list of instances of representations which have been made to the Board of Trade regarding the pollution of tidal waters or estuaries.

Exhibit 4.

I understand that the Royal Commission on Salmon Fisheries for England, Wales and Scotland have been taking evidence as to the position of sewer outfalls, the nature of the effluents they discharge and its effect on fish life. I am also informed by the Chief Inspector of Fisheries that experiments have been made in this and other countries as to the effect on fish life of the principal constituents of sewage and manufacturing effluents, and I have in my hand a reference to various reports and documents in which an account of some of these experiments will be found.

Exhibit 5

Exhibit 1.

28th January, 1893.

The Secretary,
Local Government Board.

Sir,—With reference, &c., 31st ulto ($^{116,212\ K\ (1)}_{1892}$) in which you ask to be referred to the actual instances which this Board had in view in stating that injury to health and life has frequently been traced to the eating of shell fish exposed to contamination by sewage. I am, etc., to state that the search for the documents and evidence in the various cases which have come under the notice of this Department has proved to be a matter involving a considerable expenditure of time and labour, and that they have not yet been able to obtain in every instance the detailed particulars which the Local Government Board would seem to desire.

In order, however, not to delay any longer their reply to your letter, I am to submit for the information of the Local Government Board the following statement relative to some of the cases in question.

In the year 1883 three cases of illness occurred in the Isle of Thanet, which were attributed by Dr. M. K. Robinson, of Dover, the Medical Officer of Health for that Union, to the eating of mussels taken from near the outfall of the Ramsgate sewer.

In the following year over fifty persons were seized with severe illness, which, in the opinion of the same officer, was clearly traceable to the effects of poison conveyed by shrimps, of which they had partaken, and which had been caught near the outfall of the Margate sewer.

Extracts from Dr. Robinson's official reports on the above-mentioned occurrences are enclosed herein. It will be observed that that gentleman refers in his later report to other analogous cases which had been brought to his notice.

In the year 1888 two persons who had eaten mussels gathered near the outfall of Ramsgate sewer were attacked with illness, at first supposed to be typhoid fever, but which was attributed on medical authority to the effects of eating the shell-fish in question; and in the following year a similar case of illness was similarly traced to the consumption of cockles taken

from a place similarly contaminated by sewage. The Board of Trade are not at the present moment able to furnish full details with respect to this last-mentioned case, but they have good ground for believing it to be an authentic instance of injury distinctly due to the cause indicated.

In July, 1890, five members of a family resident in Dublin died from the effects of eating mussels which had been taken from a tidal pool in Dublin Bay, which is well known to be the receptacle of sewage-contaminated waters.

The fact that the illness of H.R.H. the Duke of York, in November, 1891, was attributed, whether rightly or wrongly, to the consumption of oysters taken from Dublin Bay gave occasion for various expressions of opinion in support of the theory in that particular case, and bearing out the general view that the infection of shell-fish by sewage is a source of danger.

Among other such expressions, the Board of Trade would refer to a letter published in the "Times" of Nov. 24th, 1891 (p. 7, col. 2), purporting to give the personal experience of a physician in a case of typhoid fever which was "clearly traced" to oysters that had been temporarily laid upon a tidal bank, a few miles from Dublin, over which sewage was carried by the incoming tide.

The Board of Trade regret that they have been as yet unable to identify the author of that letter. They desire me, however, to say that no less an authority than Professor Huxley has expressed the following opinion on the general subject: "I do not see how it can be doubted that oysters taken from a bed irrigated with dilute sewage and eaten uncooked would be dangerous articles of diet. Does anybody pretend that it would be safer to take drinking water (unfiltered and otherwise unpurified) from a body of fresh water of similar dimensions to any estuary which may be under consideration at a point equally near a sewage discharge? If such a proceeding is safe, our sanitary authorities are taking a great deal of trouble in vain: if it is not safe, neither is it desirable to eat oysters, the juices of which are impregnated with sewage, in however dilute a condition."

I am to add that instances of illness and death occurring abroad through eating uncooked shell-fish have also come under the notice of the Board of Trade. In October, 1885, for example, nineteen workmen in the Arsenal at Wilhelmshaven were seized with sickness after partaking of mussels taken in Wilhelmshaven Bay, and four of them died. The circumstances attending this fatality were carefully investigated by both German and French authorities, and in an official report addressed to the French Minister of Marine by the Comité consultatif des pêches maritimes, and dated the 16th April, 1889, reference is made to this case and to the fact that Professor Grancher had found: "that oysters which are capable of causing poisoning are those which have remained in waters infected with organic matters in a state of decomposition."

In view of the circumstances above set forth, I am to enquire whether the Local Government Board are disposed to dispute the proposition, which seems to the Board of Trade so self-evident, that danger to health and life must naturally arise from the eating of oysters or mussels or other shell-fish in the open shells of which sewage or sewage matter has been deposited; or whether they would desire this department to further follow up the search which it has been making, with the view of furnishing detailed evidence relating to the case which the Board of Trade had in view in their previous letter on the subject.

(Signed) A. D. BERRINGTON.

EXTRACT from Report to Sanitary Authorities of the East Kent Joint Committee for the year 1885, by M. K. ROBINSON, M.D. (the Medical Officer of Health).

The two exceptional cases (of enteric fever) referred to above followed the eating of mussels in a raw state. They occurred at houses widely apart. The sanitary condition of the premises in each case was good, and the drinking water derived from the company's works. No connection could be traced with any previously infected source. No extension of the disease took place at either house. The mussels were eaten only by the sufferers in question and by a sister of one of them, who was sick and ill for a short time after partaking of them.

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The mussels were gathered near the outfall of the Ramsgate sewer, and eaten in an uncooked condition. If milk and water can act as a vehicle for the conveyance of enteric fever contagion, which is known to be the case, there is nothing unreasonable in believing that mussels gathered at the mouth of a sewer and consumed in a raw state might prove also capable of communicating the disease.

* * * * * *

EXTRACT from Report to the Sanitary Authorities of the East Kent Joint Committee for the year 1884, by M. K. ROBINSON, M.D. (the Medical Officer of Health).

In addition to the outbreaks (of zymotic disease) tabulated above, a remarkable occurrence of wholesale poisoning, following the eating of shrimps, was reported to the Sanitary Authority.

Between 50 and 60 people who partook of shrimps procured from a man of the name of Atwell, on Sunday morning, September 21st, were seized with severe choleraic symptoms, viz., purging, vomiting, cramp and chilliness during the night of the 21st or following day. This man sold shrimps at nearly every house in North and West Down, and sickness followed in every house so supplied, exclusive of one family to be presently noticed.

At those houses where no shrimps were purchased no illness occurred. At houses where some partook of the shrimps and some did not, those who did not eat shrimps escaped, whilst those who partook of them suffered. The shrimps were said to have been caught near the outfall of the Margate sewer on the previous afternoon, and boiled the same night. They were kept during the night prior to sale in a cottage containing three rooms on the ground floor, the rooms opening out into each other, so that the shrimps would be exposed during the night to the atmosphere of the bedrooms. Atwell, the shrimper, had been ill with diarrhœa a few days previously.

There was one striking exception to the general poisoning amongst the consumers of the shrimps, which at first appeared to indicate accidental poisoning of the shrimps during the cooking process. A sister of Atwell's purchased some shrimps of him in an uncooked condition, boiling them herself, and this woman and her family, who partook of the shrimps, did not suffer any ill effects. She, however, said that the shrimps were covered with a parasitic attachment of a gelatinous character, which was not uncommon at this period of the year, and that she was particular, as taught by her father, in cleaning the shrimps from this attachment. Afterwards it was discovered that another sister of Atwell had also bought shrimps of him in an uncooked condition, but two members of this family who partook of the shrimps suffered. Again, a neighbour of Atwell's who had caught some shrimps at a different part of the shore, boiled them in Atwell's pan, using the same water, and he and his family ate these shrimps without any bad results. This accidental poisoning of the shrimps during the boiling process could no longer be considered tenable, as the cause of the mischief, inasmuch as some of the shrimps not boiled by Atwell produced poisonous results, and shrimps caught by another man were boiled in the same water and pan and were eaten without bad results, It is a matter of regret that none of the implicated shrimps could be obtained for analytical and microscopical examination, and thus evidence which could probably have proved of the greatest value was wanting to complete the data on which to base an opinion as to the cause of the mischief. I have to be content, therefore, to record the facts which, as stated above, are, I believe, accurate and capable of being substantiated.

I will merely observe that some cases of poisoning came under my notice during 1883, which appeared to be due to the eating of mussels in a raw state, which had been caught at the mouth of the Ramsgate sewer. I have also been informed that a number of people in a Bavarian village were poisoned by eating crabs tainted with sewage. Further, that at Dungarvan, on the south-east coast of Ireland, where some people were poisoned by eating cockles, those fish were found to have attached to them a parasitic fungi (*sic*), as was also the case in another instance of poisoning following the use of cockles and oysters.

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EXHIBIT II.—SEWER OUTFALLS ON FORESHORE.

ABSTRACT OF CASES in which the Board of Trade either refused or granted a conditional consent to construction of works on foreshore.

1900—1901.

In Geographical order N.E. to N.W.

Name of Applicant.	Locality of Outfall.	Action taken by Board of Trade.
Riccall Urban District Council.	At Barlby on River Ouse.	Board of Trade consented on Council undertaking (1) to carry out the works (septic tank, etc.) shown on plan, and such further works as might be necessary to limit the discharge of effluent to the ebb tide, and (2) to comply with any standard which the Royal Commission on Sewage Disposal in their Report might set up in respect of sewage works in a similar situation.
Sheringham and Caistor Hotels and Land Company, Limited.	Caistor - -	Board of Trade consented on condition (1) That end of sewer should be marked by a beacon or buoy if required; (2) That no sewage should be discharged on flood tide; (3) That the sewer should not be utilised for discharge of sewage or other matter from any area or premises not shown on the plan.
Walton-on-the-Naze Urban District Council.	Walton - -	The Council at first proposed to discharge the sewage into Walton Channel, but the Board of Trade refused to consent on fishery grounds. An amended scheme was then submitted, under which the discharge would be into open sea. The Board thereupon consented on condition: (1.) That pipe should commence at a specified point on shore north of the breakwater and terminate at low water of O. S. tides. (2.) That septic and storage tanks be constructed. (3.) That effluent be discharged on ebb tide only.
Wivenhoe Urban District Council.	River Colne -	Consent given on Council undertaking:— (1.) That outfall sewer should be open to view, and that effluent should be open to inspection by officers of the Board of Trade, Corporation of Colchester, and of the Colne Fishery Board, duly authorised. (2.) That the Council would keep a record of the condition of the effluent, and execute such further works as may be necessary to comply with any standard which the Royal Commission on Sewage Disposal in their Report may set up in respect of sewage works in a similar situation.
Burnham-on-Crouch Urban District Council.	Burnham -	Board of Trade were of opinion that scheme did not sufficiently safeguard shell-fish interest. Pipe would be of small capacity and low gradient, discharging into a creek at line of high water, and would be tide locked at high water. It was suggested to Council that level of outfall should be raised and point of discharge placed more directly under the influence of the ebb tide. Discharge of effluent should commence about time of high water and terminate not later than two hours before low water. Provision to be made also for storing the sewage between times of discharge. Council were asked to re-consider their scheme.
Isle of Thanet Rural District Council.	Birchington -	Board of Trade declined to consent to use of foreshore, as they were of opinion that the sewer outfall would be a source of possible danger to the oyster and mussel beds over or near which the effluent would be discharged. The point of discharge was placed above ordinary low water mark, and the mussel beds extend for a considerable distance beyond it seawards. There is little tidal current, and even if the outfall were extended seaward the effluent would be liable to be carried inshore by wind or tide. The Board of Trade, while not disputing the value of the bacterial treatment to which it was proposed to subject the crude sewage matter, felt that there must be a risk in certain circumstances that sewage which was not innocuous might escape from the tanks. Further, if permission was once granted to construction of the outfall the Board of Trade would have no power to enforce any alteration of the works. Nevertheless, the Board have expressed their willingness to consider any modified scheme which the Council may submit.
Blean Rural District Council.	Hampton, near Herne Bay.	The Council applied to the Local Government Board for sanction to a loan for sewerage purposes; an inquiry was held and the fishermen and the Local Fisheries Committee for the Kent and Essex district strongly opposed the scheme. In reply to a request for their observations the Board of Trade informed the Local Government Board that they gathered that it was proposed to discharge crude sewage into the sea at all states of the tide, and that having regard to the proximity of shell fish beds and to the set of the currents in the locality the objections on fishery grounds were entitled to very serious consideration.
Southampton Town Council.	Extension of outfall in River Itchen.	Consent given on Council undertaking:— (1) That effluent shall be discharged only within period between two hours before commencement of ebbing tide and thirty minutes before following low water. (2) That works shall be open at all reasonable times to inspection by officers of the Board of Trade.
Portland Urban District Council.	Isle of Portland	Objection was taken to site of one of the outfalls on fishery grounds. Fresh plans were submitted and the Board of Trade consented to the construction of the outfall on a site where the tidal conditions were more favourable.
Plympton St. Mary Rural District Council.	River Plym at Longbridge.	It was found that the Admiralty licence would provide that no solid matter should be discharged and that the effluent should be innocuous; the Board of Trade therefore consented on condition:— (1) That discharge should take place between one hour before high water and two hours before low water. (2) That power of inspection be given to officers of the Board of Trade and Board of Conservators of Tamar and Plym fishery district.
J. Ford, Esq. -	River Yealm, Newton Ferrers.	Board of Trade consented on conditions following:— (1) Pipe to be carried beyond end of pier. (2) Sewage to be discharged only on ebb tide and at least one hour before low water. (3) Sewage matter to be stored during time discharge is stopped. (4) Indicator to be provided showing position of sluice valves. (5) Works to be open to inspection by officers of Local Authority or Board of Trade.

Name of Applicant.	Locality of Outfall.	Action taken by Board of Trade.
Newnham Urban District Council.	New outfall in Severn at Newnham.	Board of Trade consented on Council undertaking that the volume of sewage discharged from the new outfall should not exceed that at present discharged by the existing sewer. In this case the Board of Trade departed from their usual practice of requiring the sewage to be purified before discharge, but in so doing, they were solely influenced by the assurance given by the Council that it was not proposed to discharge an increased volume of sewage. Should it prove impracticable for the Council to comply with their undertaking the Board of Trade would feel it necessary to require that a proper system of filtration should be adopted, and that the effluent should be discharged on the ebb tide only.
Llanelly Urban District Council.	Burry Port	Board of Trade consented on condition :— (1) Sewage to be previously treated by septic system. (2) Sewage to be discharged only on ebb tide and not less than two hours before low water. [Council also undertook on their own initiative to empty storage tanks within an hour of raising the valves.] (3) Automatic indicator to be provided.
Aberystwith Corporation.	Extension of outfall at Aberystwith.	Board of Trade consented on condition :— (1) Sewage not to be discharged except between high water and two hours before cessation of outflowing stream from the harbour. (2) Indicator to be provided.
Connah's Quay Urban District Council.	River Dee, at Connah's Quay.	An Inspector of Fisheries inspected site of works, and in accordance with his recommendations the Board of Trade declined to consent to the use of the foreshore unless the scheme were accompanied by adequate measures for purifying the effluent.
Lower Bebington Urban District Council.	River Mersey at Bromborough.	Consent given on condition :— (1) Sluice valve of storage tank not to be opened except during ebb tide. (2) Automatic indicators to be provided. (3) Works at all times to be subject to inspection by officers of the Mersey Conservancy.
Ulverston Urban District Council.	River Eea, in connection with Cark Sewerage.	Council informed that Board of Trade could not consent unless— (1) Provision was made for purification of effluent. (2) Council constructed such storage tank or tanks as might be necessary to secure that the discharge should only be on ebb tide between high water and two hours before low water.
Ulverston Urban District Council.	River Duddon, at Foxfield.	ditto - ditto.
South Westmorland Rural District Council.	River Bela, at Milnthorpe.	As it appeared that a modification of scheme was contemplated by the Council, the Board of Trade suggested to the Local Government Board whether effect could not be given to the representations of the Board of Salmon Conservators for the river by subjecting the sewage to treatment, and by discharging the effluent on the ebb tide, unless under any amended scheme the outfall was carried further down the estuary and discharged under such conditions as would reduce the objections to its being discharged untreated

EXHIBIT III.—POLLUTION OF SALMON RIVERS.

SPECIMEN CASES in which the Board of Trade have communicated with the Local Government Board.

Severn - - -	Worcester sewage.	In 1892 and again in 1896, Mr. C. E. Fryer, Inspector of Fisheries, made an affidavit regarding the pollution of the Severn by the sewer outfalls at Worcester. (This was in connection with the proceedings instituted by the Local Government Board against the Corporation.)
Wye - - -	Monmouth sewage.	Communications were addressed to the Local Government Board in connection with representations made by the Wye Fishery Board in 1896. An inquiry was held and the original scheme was much altered. The Wye was not to be interfered with, and the sewage effluent to be purified before its discharge into the Monnow, a tributary of the Wye.
Usk - - -	Pollution at Brecon by sewage from Christ's College.	In 1895 the Board of Trade forwarded to the Local Government Board a complaint received from the Conservators. The Local Government Board endeavoured without success to induce the Brecon Corporation to act in the matter, but in 1897 the Conservators reported that the college authorities had at last taken satisfactory steps to prevent pollution.
Trent - - -	Fish poisoning from refuse discharged from works of Hardman and Company, on Ford Green Brook, Milton.	In 1895 the proceedings instituted against the firm by the Trent Fishery Board failed because the defendant alleged that he had used the best practicable means within a reasonable cost to render the matter harmless. cf. Rivers Pollution Prevention Act, 1876, Section 6. In 1900 the Fishery Board complained to the Board of Trade and the matter was referred to the Local Government Board, who, after considering the report of their inspector, decided to refuse an application from the Staffordshire County Council for consent to prosecute the owners of the works.
Trent - - -	Pollution of Ecclesbourne by Wirksworth sewage.	In July, 1900, the Fishery Board called attention to this matter and an Inspector of Fisheries visited the place. His report was communicated to the Local Government Board, who, in turn, referred the Fishery Board to the power to institute proceedings under the Rivers Pollution Prevention Acts, explaining that the Local Government Board had no power themselves to enforce those Acts.
Trent - - -	Pollution by Nottingham sewage.	In July, 1896, the Conservators called attention to the serious destruction of fish in the river, "thousands of fish of all kinds for many miles" being killed. A representation was made to the Local Government Board in the matter, and again in 1898 in connection with an application by the Corporation for a Provisional Order to enable them to acquire additional land for a sewage farm. In 1899 and 1901 the Local Government Board sanctioned loans for the Sewerage Scheme on condition that the Town Council would not at any time allow unpurified sewage to pass into the river. But the Conservators say the effluent is often very bad.

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EXHIBIT IV.—SPECIMEN CASES of Complaints received from Salmon Fishery Boards regarding Pollution of Tidal Waters.

Fishery District.	Stream Affected.	Particulars of Complaint.	Reference Authority.
Eden	Eden	The Board of Conservators frequently complain of the pollution caused by the sewage of Carlisle, which in dry summers prevented, it was believed, the sea trout and herlings from running freely.	33rd Rep., p. 27. 34th Rep., p. 26. 36th Rep., p. 26, &c.
Lune	Lune	In 1898 the Conservators complained of the pollution of the river by sewage and other matters discharged from Lancaster, the Gas Works, Lune Mills, and Royal Albert Asylum. In the following year they applied to the Local Government Board for an Order declaring the estuary to be a "stream" within the meaning of the Rivers Pollution Prevention Act, but the application was not granted.	F/H/7019/98. 39th Rep., p. 40.
Ogmore	Ogmore	Pollution caused by sewage from Bridgend. Frequent complaints were received, and in 1897 the Fishery Board represented that the pollution was most serious and increased from year to year. The Board of Trade communicated with the Local Government Board in the matter and ascertained that a sewerage scheme was in contemplation. This scheme has been commenced and will be completed this year.	37th Rep., p. 48. 7050/98. 39th Rep.
Rhymney	Rhymney	In 1887 the Local Government Board, on the application of the Board of Conservators, issued an Order determining the tidal waters of the Rhymney to be a stream within the meaning of the Rivers Pollution Prevention Act 1876; in their annual return for that year the Conservators stated that the Act was unworkable and useless.	1924/96.
Usk	Afon Llwyd.	The Conservators in their annual returns frequently refer to the pollution of this stream and succeeded in obtaining the grant of an Order from the Local Government Board declaring the tidal waters to be a "stream."	33rd Rep., p. 50. 35th Rep., p. 55.
Exe	Exe	Pollution by sewage from Exeter. The attention of the Board of Trade was drawn to the matter in 1895 by the Board of Conservators. Inquiries were held by the Local Government Board in that year and again in 1900. The matter is still pending.	14580/00.
Stour (Essex).	Gipping and Orwell.	In 1892 and in the annual return for 1893 the Board of Conservators reported that very offensive matter was discharged from tanneries into tidal waters at Ipswich, which it was believed stopped the ascent of migratory trout.	1066/92. 33rd Rep., p. 68.
Yorkshire	Ouse	Barbly Sewerage Scheme.—The Board of Conservators strongly objected to the discharge of crude sewage into the river under the scheme.	1119/00.
Tyne	Tyne	In 1895 the Board of Conservators stated that "Pollutions increase each year in number and intensity, owing in great measure to the extended use of disinfectants; during the long drought in summer numbers of fish were killed by the sewage in the upper tidal waters, and were taken and seen along the river down to the sea. This was caused by the flood tide forcing the accumulated sewage during the hours of low water up to the upper parts of the tidal basins where there was no fresh water to dilute it." In 1897 the Clerk to the Conservators reported that the caustic soda used to disinfect Byker Burn was carried into the Tyne by a small flood, with the result of destroying all the fish in eleven miles of tideway.	35th Rep., p. 81. 27th Rep., p. 182.

EXHIBIT V.—REFERENCES TO REPORTS AND DOCUMENTS REGARDING EXPERIMENTS.

Although the Board of Trade have never made investigations with regard to the effect on fish life of the principal constituents of effluents of sewers or manufactories, reference might be made as regards floating fish, to the work done by Nitsche and Tharaud, by Weigelt, by J. König, by Hoppe Seyler, and Duncan, and by Saare and Schab ("Die Verunreinigung der Gewasser deren schädliche folgen sowie die Reinigung von Trink und Schmutzwasser." Vols. I. and II., by Dr. König), by Penny and Adam in Scotland (Fourth Report of the Rivers Pollution Commission), by the United States Fish Commission in America (United States Commissioners' Report, 1880, Bulletin of the United States Fish Commission, Vol. V.), and by Dr. Houston (Second Report to the London County Council on the bacterial treatment of sewage).

In these reports, experiments are recorded as to the effect on fish of effluents from paper and bleaching works, wool-washings, dye works, gas works, coal washings, tanneries, soda and potash works, ammonia works, flax water, chemicals in other works, and domestic sewage.

According to these experiments, it appears that effluents from the above sources of pollution, unless sufficiently diluted with water, will kill the parent salmon when passing through the tidal waters to the spawning beds in the upper waters, or smolts descending to the sea, either by (1) direct poisonous action, or (2) using up the oxygen in the water.

With regard to domestic sewage, J. König points out that fish are not injured by the solid matter in fresh sewage, but by its putrefaction in warm weather, when it becomes injurious, partly by using up the oxygen in the water, and partly by giving off various poisonous substances.

He also gives the results of Hoppe Seyler and Duncan's experiments showing that oxygen may fall to 2·2 c.m. per litre (0° C and 760 m.m.), or about one-third of the normal without injury to trout.

8770. (*Chairman.*) As I understand the Board of Trade have never done anything in the way of conducting chemical or bacteriological examinations?—No.

8771. And the Board of Trade in any action they have taken have thought only of the welfare of the fish, I suppose?—Yes.

8772. They do not pretend to look after human beings?—No.

8773. Might one say generally that somebody complains that an oyster bed is being damaged by sewage, and then you lay down an order to prevent the nuisance?—No, we have no power to do that; our real power only exists in this, that as guardians of the foreshore we have power to prevent works on the foreshore or on the bed of the sea.

8774. (*Mr. Power.*) They are not retrospective, your powers, as to sewage disposal?—No.

8775. It is for new works on the foreshore only?—New works on the foreshore, that is the only power we have got. The Sea Fisheries Committees have power to make bye-laws, but outfall sewers by public health authorities are exempted from the operation of those bye-laws.

8776. Their bye-laws are retrospective to some extent then, with that exception, are they?—Yes, I suppose they can proceed under their bye-laws.

8777. The deposit of sludge and things of that kind, I suppose their bye-laws would affect, would they not?—The words of the Act are:—"For prohibiting or regulating the deposit or discharge of any solid or liquid substance detrimental to sea fish or sea fishing." But Section 13 of the Act says: "Nothing in this Act shall authorise a Local Fisheries Committee to make any bye-law affecting any power of a sanitary or other local authority to discharge sewage in pursuance of any power given by a general or local Act of Parliament or by a provisional order confirmed by Parliament."

8778. That is, Fishery Committee bye-law could not affect power the authority has already exercised; but could such bye-law affect prospective action of the local authority?—Yes, I think so.

8779. Would you give the reasons, Mr. Pelham, for the exemption of certain areas from bye-laws? There are some exempted in the Thames below the Mouse light-ship, the Mouse Pond, and then again there are certain exempted areas in regard to Sussex, Lancashire, West Cumberland districts. How did exemptions come about?—I am afraid I could not answer that; I take it that there were certain places where it was considered that the deposit of refuse and sludge would not be injurious.

8780. I think probably in the case of the Thames it was the sludge from the Cross Ness and Barking outfalls?—Yes, I think so.

8781. I know that fishermen said it interfered with the sprats, but as to these other places, was it for similar

reasons that certain areas were exempted?—In some cases, if I remember right, the Admiralty wished certain places to be exempted. They wished their contractors to be able to put stuff down.

8782. (*Chairman.*) There is just one question as to the law I would like to ask you. The 15th Section of the Act to which you have referred provides as follows. "Nothing in this Act shall authorise a local fisheries committee to make any bye-law affecting any power of the sanitary or other local authority to discharge sewage in pursuance of any power given by a general or local Act of Parliament, or by a provisional order confirmed by Parliament." But supposing that the power of the sanitary or other local authority arises not from any general or local Act of Parliament, or any provisional order confirmed by Parliament, but, for instance, supposing it arises from old custom, then you would have a power of interference, I suppose?—This relates to bye laws, not the power of the Board of Trade. I should just mention that in the first place, but I suppose your lordship refers to the power to make a bye-law when the bye-law could apply?

8783. Yes, quite so?—Well, I take it that discharge of sewage would be always under either a general or a local Act, I take it that this would exempt any discharge of sewage by a public health authority. My impression is that the bye-law could not control discharge by a statutory authority.

8784. Well, but I should think probably there are many cases of sewage being discharged according to old custom without any special law at all?

8785. (*Mr. Power.*) Yes, there would be many instances in which the sewage of a place discharged by many outfalls into tidal water, and by way of experiment the authority might seek to combine all these into one outfall. Then they would come under the bye-law of new works, would they not?—No, they would not come under the bye-law, they would have to apply to the Board of Trade for permission to put works on the foreshore, and then we should try to control it to some extent; but I take it that the bye-law of the local fisheries committee would not relate to any discharge of sewage by statutory authorities.

8786. Discharge of sewage in any way?—I think not. You see it is under a general Act, and I take it that their discharging sewage as the Urban District Council they would be acting under the Public Health Act, that is a general Act.

(*Sir Michael Foster.*) Lord Iddesleigh's question was rather, were there no places where from old time a certain amount of sewage had been deposited into tidal water without any sanitary authority having been established to direct it.

(*Mr. Power.*) Quite so, from old times?

8787. (*Chairman.*) Yes?—I should say that in the case of a farmhouse discharging into a creek the bye-law might apply, but that if it was dealt with by the Urban District Council or by the Rural District Council, then the discharge would be under a general Act. A particular outfall is not authorised by the Act, yet it is a statutory authority discharging sewage under a general Act, under general powers.

8788. (*Sir Michael Foster.*) I suppose the theory is that in such cases matters are arranged for by that authority—the local authority?—Quite so.

8789. And that the Fisheries Committee need not interfere?—It would be very undesirable that the Fisheries Committee, who are not a very substantial body generally, should be trying to control discharges by the local sanitary authority.

8790. And moreover there is no need for their intervention, because the public health is guarded by the local authority?—I am afraid the local authorities do not consider very much what becomes of the sewage after it is once in the water; it goes away from their district, and whether it injures oysters three miles off in somebody else's district they do not much care.

8791. Then in that case you have power to intervene?—No, I do not think we have. We have only power to intervene in this way, that we can sanction as the foreshore authority, or prohibit the erection of the outfall sewer, and we try to attach conditions sometimes; we have no power to enforce them.

8792. A case in this point, that for some time, we will say, it was a small place, and relatively a small quantity of sewage, and that was doing no damage to the foreshore, but there is an increase of the population, or there is some change in the amount or in the nature of the sewage, and in consequence of that damage is done, say to the oyster beds and so on. Have you not power to intervene in that case?—No, unless they come to us and ask us for an enlargement of the sewer.

8793. (*Mr. Power.*) New works, in fact?—New works.

8794. (*Sir Michael Foster.*) If there are new works, and such a change would probably necessitate new works, then it is safeguarded?—Yes, but we should find it very difficult to enforce, where we had already sanctioned something years ago and the thing had been going on we should find it very difficult to refuse an improvement, very difficult indeed.

8795. (*Mr. Power.*) And that alteration, although not possibly the best, is infinitely better than what obtained before?—Quite so, that very often happens. *Qua* Fishery authority we have no powers except to sanction bye-laws by the local Sea Fisheries Committees, who cannot touch the sewers; *qua* owners on behalf of the Crown of the foreshore, we have power to prohibit any work on the foreshore, in some parts of England, not all parts of England.

8796. (*Sir Michael Foster.*) Not all parts?—The foreshore is vested in us where it was vested in the Woods before 1865, but there is a good deal saved to the Woods. There is a good deal vested in the Duchy of Cornwall and a good deal in the Duchy of Lancaster, and a good deal of foreshore is vested in private owners, we hardly know how much, by ancient grants from the Crown, and there we have very little control. They have to come to us in the case of new works. In the interests of navigation it is very difficult for us to say, "You shall not put your sewer there because you are going to injure oysters," when we have only got control of navigation.

8797. (*Mr. Power.*) You say, Mr. Pelham, that no works can be constructed on the foreshore or bed of the sea without the Board of Trade's consent: is that *quâ* navigation?—That relates to where the foreshore belongs to the Crown, and is under the control of the Board of Trade.

8798. (*Sir Michael Foster.*) Have you any idea what is the portion of the whole foreshore which comes under your care in that way; is it one-half, or two-thirds, or what?—I should say rather more than that. Of course, all Lancashire and Cornwall are excepted. The Woods have also kept to themselves every part of the shore which is opposite Crown property, and the private rights are very difficult to ascertain. We constantly are telling people that the Crown has a *primâ facie* right to the foreshore, and you must not do anything there till you prove your claim, but until some question arises people do not claim the foreshore, and then we have to refer sometimes to the law officers, and we admit the claim if they make out a good case, or sometimes we file an injunction.

8799. (*Major General Carey.*) Have the Board of Trade had evidence at any time that crude sewage is injurious to the life of sea fish?—Our impression is that crude sewage is not injurious to sea fish, except where it is discharged in the immediate neighbourhood of shell fish, and there the injury is not so much directly to the shell fish, but is to the person who may eat the fish raw, the fish possibly containing germs of poison, or possibly the water in which the fish is. A man may swallow the fish raw, and therefore may take in the poison.

8800. (*Professor Ramsay.*) Has there been any evidence before the Board of Trade as to whether chemically purified effluents have any action of the kind you mention?—No, we are very anxious for evidence on that point, very anxious indeed. In one or two cases in which we have lately corresponded with the Local Government Board we have asked for some assurance from the Local Government Board that the effluent would not be injurious to human life.

8801. I mean through oysters?—Through oysters, yes.

8802. (*Major-General Carey.*) But as regards salmon which pass from the tidal water into fresh water, is there any reason to suppose that crude sewage would be injurious either to the fish themselves or the persons eating the fish?—We have no evidence that there would be any injury caused to the person eating the fish. In the case of salmon, what we fear is the injury to the salmon themselves. In some cases we have representations made that the salmon are poisoned, or that the fish cannot live in the water, therefore, they do not go up the river to their spawning beds. The result

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is that the river ceases to be a salmon river; the salmon cannot get up to breed, and therefore they do not come even into the estuary.

8803. With reference to rivers in which the water is very heavily polluted, where the fish cannot live?—Yes.

8804. Now, taking the case of rivers in which the water is sufficiently clear or sufficiently full of oxygen to enable the fish to live without detriment to their health; would any objection be raised to crude sewage being discharged into the tidal water?—No, except on the ground that if everybody else was to go on doing it the time might come when the amount of sewage was so great, that the salmon could not pass up the river.

8805. (*Mr. Power.*) You speak of complaints, and you say you have a list of instances of representations which have been made to the Board of Trade as to the pollution of tidal waters or estuaries; are you putting in those?—Yes.

8806. Then, again, you have references to reports of experiments which have been made as to the effect on fish life of the principal constituents of effluents. Do you put those in also. We should be very glad to see them?—Probably I might hand you that; it is hardly my evidence, but it has just been handed to me by the Chief Inspector. It is not supposed to be exhaustive in any way.

8807. Then the representations which have been made to the Board of Trade in regard to the pollution of tidal waters and estuaries, that is a separate matter is it not?—That is a separate matter.

8808. (*Chairman.*) Have you any experience as to whether, in the event of a sewage outfall being moved away from an oyster bed the oysters move after it?—No; I do not think we have any information on that head.

8809. Then, as far as I can see, your powers are very limited, because if any authority is discharging you cannot interfere with them?—No, our powers only come incidentally, because we who are the Fishery Authority happen also to have for other reasons the control of the foreshore, of the coast, and the estuaries.

8810. Yes, but if a local authority is already discharging into the sea you cannot interfere with them?—No, we cannot.

8811. And your interests are only concerned in the preservation of the foreshore itself and of the fish?—Yes.

8812. Officially speaking, you care nothing about the public health?—I think we feel that we ought to leave that to the sanitary authorities. We are only indirectly interested in this way, that if human health suffers there is a sort of scare if it is attributed to oysters, and the trade suffers, and we do our best to protect the trade.

8813. (*Mr. Power.*) You say that you consider the consent of the Board of Trade should be rendered necessary to any outfall sewers on the coast of estuaries or rivers, whether or not the estuary is vested in the Board of Trade, and you go on to say, "and, further, this Board should be empowered to attach conditions to such consent, and to enforce compliance with such conditions." Were you thinking of setting up a supervision to see the conditions that had been enjoined were always observed. Do you suggest that the Board of Trade should be empowered to attach conditions to consent, to enforce compliance with those conditions, and to see that they are observed?—Well, we should, of course, have to act in those matters through the Sea Fisheries Committees. We have no inspectors who could watch the coast for that purpose, and we should only act where our attention was called to the non-compliance with conditions by the Sea Fisheries Committees.

8814. You would apparently await representations from the coast?—Yes.

8815. (*Sir Michael Foster.*) The Fisheries Committees would report to you and then you would take action?—I suppose so. In certain cases the Sea Fisheries Committees might take action themselves.

8816. (*Mr. Power.*) Have there been any instances in which Lords of the Manor, as owners of the foreshore, have consented to works that you would have disapproved of, or refused your consent to?—Well, I can hardly say that. There have been a good many cases where Lords of the Manor have assented to works, and we have found it out afterwards, and we have remonstrated with them on the ground that they were asserting their title to the shore, which we did not admit. I do not know that we know of any cases where the shore admittedly belonged to the Lord of the Manor, where they had sanctioned something which we should not have sanctioned. Of course, there are discharges in some of the great tidal rivers of crude sewage numbered by hundreds you might almost say—the Ouse and the Tyne, and different rivers.

8817. (*Mr. Cotton.*) I only wanted to ask Mr. Pelham one question, and that was as to the effect of all you have been saying upon Ireland? You have the same power with regard to the foreshores in Ireland that you have here?—Yes; we have in Ireland.

8818. Have you ever refused sanction to structural works in Ireland on account of the sea fishing?—I think not. We have only very lately taken up the question in England, and it was on account of representations which were made to us by our Sea Fisheries Committees.

8819. Does that extend to Ireland?—No that does not extend to Ireland. We have nothing to do with fisheries in Ireland, they are under the fishery inspectors, or, I think, now under the new Agricultural Department in Dublin. We have nothing to do with fisheries, so we do not hear the fishery complaints.

8820. And not hearing any complaint, you would not take any action?—No.

8821. I mean apart from danger to the structural works or risk?—Quite so.

8822. You would not look into the fishery question?—No, we should not.

8823. (*Mr. Power.*) The fishery committees have only been established about a dozen years, have they?—Yes, that is so.

8824. (*Dr. Russell.*) Is the jurisdiction of the Board of Trade over tidal foreshores in the interests of navigation wider than as owners of the foreshore?—Yes, it is wider in this way, that it extends everywhere.

8825. That is just what I wanted; I thought so?—Yes.

8826. So that any proposal to discharge sewage over the foreshore one way or another would come to you?—The works would come before us, but we should not like to object very much on the ground of fisheries if our jurisliction was only as to navigation.

8827. Yes, it is narrower; the scope of your interference is narrower?—Yes.

8828. Then there is an allusion here to Boards of Salmon Conservators. I do not quite understand that these are different from the Fishery Boards?—Yes, they are different from the Sea Fisheries Committees. The Boards of Conservators look after particular rivers.

8829. Oh, yes?—In the interests of salmon. Their areas slightly overlap the areas of the Sea Fisheries Committees.

8830. (*Professor Ramsay.*) What is meant by works on the foreshore? Is it, for instance, a farmer putting a drain pipe on the foreshore?—Yes, any interference with the soil of the foreshore; even the removal of material would be a work.

8831. (*Dr. Russell.*) But I suspect that, as a matter of fact, numerous villas have been put down, and pipes stuck out into the shore that you never heard of at all?—Very often that is the case.

8832. (*Sir Michael Foster.*) I suppose the amount of foreshore which is claimed by the Admiralty is very slight, is it not? You said, I think, that the Admiralty claimed?—No; the Admiralty asked us to exempt certain areas in order to enable their contractors——

8833. To dump down?—To dump down their stuff which they have taken from the dockyard ports.

8834. That, of course, is a very limited thing?—Yes; a very limited thing indeed.

(*Chairman.*) We are very much obliged to you.

Dr. JOHN CLOUGH THRESH, M.D., D.Sc. D.P.H., F.I.C., Medical Officer of Health of the Essex County Council, called; and Examined.

8835. (*Chairman.*) You are Dr. Thresh, a Fellow of the Institute of Chemistry?—Yes, I am.

8836. And Medical Officer of Health to the Essex County Council?—Yes.

8837. Lecturer on Public Health at the London Hospital?—I am.

8838. I think you are personally acquainted with instances of raw sewage or trade refuse going into tidal waters?—In a proof I sent I mentioned that in many instances the sewage is partially treated before going into our tidal estuaries.

8839. Then perhaps you would give us a general statement of your views?—Simply based on my experience in Essex. My county is bounded on the east by the ocean, and on the south by the River Thames, and also we have three or four tidal streams which intersect it. Of course, most sewage goes into the Thames and into one estuary, the Barking Creek. That Barking Creek receives the sewage of Woodford, Buckhurst Hill, Wanstead, Ilford, East Ham, Barking, and then enters the Thames at the creek mouth close to the outfall of the Metropolitan Sewage Works, so that you have there flowing into the Thames the partially treated sewage of some 200,000 people. Then lower down the Thames we have Grays Thurrock, Leigh, and Southend, all discharging more or less crude sewage into the river, and at the very mouth of the Thames there is Shoeburyness. At Shoeburyness, at the very mouth of the Thames, there is also crude sewage discharged. Most of the complaints we have had in the county have been in connection with Barking Creek, a tidal creek, which goes from the Thames through Barking to Ilford, where a large amount of sewage is cast into it, and the complaints have chiefly been in connection with nuisances arising from the smell, the smell being worst near the town of Barking after it has received the sewage of about half a dozen different towns. Then the sewage of Barking itself and of East Ham is backed up by the tide also as far as Barking town, so that altogether the sewage of about 200,000 population practically passes through the town of Barking, or is washed up to the town of Barking, and there there is a great deal of stagnation and deposition of black mud, and during the summer months there are continuous complaints of the odours given off by the mud and the river water, which probably at some times is more than half of it sewage or sewage effluent.

8840. (*Sir Michael Foster.*) More than half?—More than half. A considerable number of people live round the quay at Barking, and here we have constant complaints of the people suffering from sore throats and from nausea and malaise, which they attribute to the sewage. There is very often an effluvium nuisance there. I have assured myself by visiting frequently, and I think that some of those complaints as to ill-health caused by the sewage are well founded. No doubt all the complaints are not well founded, but the Medical Officer of Health there is a very energetic and competent man, and his investigations led him to the conclusion that a good many of these cases of ill-health there are due to emanations from the river.

8841. What are the nature of his investigations; how does he come to that conclusion?—He has the largest practice in the town, and he finds that certain throat affections are more common there than they are in other parts of the town. Of course, the whole district is malodorous. There are works of a noxious character. An enormous quantity of refuse from London is brought and tipped on to the marshes here. The district is a most unattractive one, and last year we made a number of experiments in connection with the air, microbes in air, especially in connection with these refuse tips, to find the number of microbes in a certain amount of air in different parts of Barking, the result being that we found there were from 10 to 100 times as many down near the river where the rubbish tips are than in the town itself; but that was more in connection with the rubbish tips than in connection with the sewage.

8842. Well, but would the sore throats be due to the rubbish heaps?—Some, possibly so.

8843. Not to the sewage?—Quite so; only the sore throats are, just at the part where the emanations from the sewage are worst. I made investigations myself at a number of houses here which are fairly close to the rubbish tips, and I was rather surprised to find that there were no complaints. But what caused that investigation originally was the fact that Barking has probably the highest death rates from infantile diarrhœa of any town in the country, and whether it was the emanations from the various sewage works or the emanations from the rubbish tips, or something in the condition of the soil and situation of Barking is a question which we want to ascertain. At the present moment we are not able to say whether this is due to one or the other, but I found there were very few cases of infantile diarrhœa down by the creek near where the rubbish tips are; most of them occurred actually in the town of Barking.

8844. Therefore were probably due to the rubbish tips one would say?—I thought they were not due to the rubbish tips and not probably due to the sewage.

8845. So that it is really only the sore throats that you seem to attribute to the sewage?—I do not assert anything. I am simply stating what I know and what I am informed, that round the Creek there is a considerable number of people who suffer from sore throats and that they attribute it to the emanations from the sewage.

8846. And the Medical Officer of Health does also?—And the Medical Officer of Health does also. I have been there, and I can say there are emanations and sore throats; I cannot assert anything else.

8847. And not elsewhere?—And not nearly so numerous elsewhere. Notwithstanding the enormous amount of sewage which is passed into the Thames here I have never had a single complaint from any one that there are any emanations from the river of an unpleasant character. There has been no complaint from any medical officer of health, nor has there been any complaint from persons residing near the river there of any nuisance arising from the sewage after it has once got into the Thames. The complaints are received higher up before it has got mixed with the large volume of Thames water. Then while we are on the Thames I may go on to mention the curious fact of which as yet I have got no sufficient explanation that all the districts that border on the banks of the Thames have a very much higher mortality from typhoid fever than the other parts of the county. As a matter of fact, it varies from two to three times the amount, the case rate and the death rate, whichever you take. And that is not an accidental occurrence one year now and again, it is every year, every year without exception. I have given in the table the case rate and the death rate in the various districts which are bounded by the Thames, and in the remainder of the county, which shows that for 10 years, 1891 to 1900, the case rate in the districts on the Thames was 1·9 per 1,000, whereas in other parts of the county it was only ·83. The death rate was ·28 and the death rate in other parts of the county only ·12, and the figures show that this excess occurs every year.

8848. Do you know what the death rate is compared to other counties?—From typhoid fever it is a little higher, I think, but not exceptionally so, taking the whole of the county. Then this morning it struck me that there is another place in the county where sewage is thrown on to the foreshore and I looked up the statistics. It is a place called Brightlingsea. You have it on the Essex map; it is on the estuary of the Colne. The sewage there is cast on to the foreshore. It has only been made into an urban district within the last few years, so that I have only got separate statistics for those years. In looking up the reports of the Medical Officer of Health for the Tendring District, in which Brightlingsea is situated, there is constant reference to the fact of typhoid fever in Brightlingsea, but he does not give me the number of cases or deaths. But since it was formed into a separate district I have got the number of cases. I find in 1897 there were eight cases, three cases in 1898, and four in 1899. The population is 4,474, which gives us a case rate of 1·1 per 1,000 for the average which again is higher than for the remainder of the county. But since the sewage has been disposed of after treatment, which commenced about a year ago, during last year they had one case. I know the Medical

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Officer of Health in that district had an impression that the casting of the crude sewage from a number of separate outfalls on to the foreshore was one of the causes of typhoid fever being prevalent there every year, and it may be a coincidence but last year, after treating their sewage and only letting the treated sewage go into the river further out, instead of having four to eight cases they only had one case.

8849. Their water supply remaining the same?—Their water supply is not better now than it was then. No; it is exactly the same. They got two years ago a loan for a public water supply, but the water is not laid on to the houses yet, so it would be exactly the same. If it has been laid on it has been done within the last month or two. Then if we take these districts, going down the Thames, in order, we find there is most typhoid fever where there is most mud exposed. If you have a map showing the foreshore—I have not got it all on one map—you will see that towards Grays there is practically no mud. It is only when you get below Canvey Island that you get this mud exposed. When you get beyond Grays we find that the typhoid fever rate goes up enormously. For instance, in Rochford District, which is the extreme south-east, the case rate is 3·3 per 1,000; in Leigh, which is an urban district, just between Canvey Island and Southend, it is 6·75. This is the average for 10 years, not for a single year. Southend, which casts its sewage without any treatment on to the foreshore, was 4·9; Shoeburyness, which did the same, was 9·0 per 1,000. That is to say, in those four districts we have a typhoid rate of about seven or eight times that of the remainder of the locality, and the mortality is also excessive, and in about the same proportion. At Southend and Shoeburyness and at Leigh, until just recently, the whole of the sewage was cast on to the foreshore without any treatment whatever.

8850. Leigh is a place rather high up, is it not, the village on the hill?—Well, the old village is right down on the beach, but the new portion which has been built and developed lately is on the top of the ridge which runs from Southend almost parallel with the Thames.

8851. This takes in the new part, I suppose, the figures you have given us?—This takes in the new part, but of course the new part has only begun to be developed; within the last two or three years there has been very little building indeed until quite recently. I went into this in connection with water supply, and I cannot trace the slightest connection between water supply and the excessive prevalence of typhoid in those districts. Southend has probably the purest water supply in the county; it is derived from deep wells about 1,000 feet deep; at Shoeburyness there has been no improvement, although they also have put down a well which is 400 or 500 feet deep, and which yields an exceedingly pure water; and up to the present there is no improvement in Leigh, although three years ago they also got a deep well. Prior to that time they used shallow well waters which undoubtedly were polluted. Taking the whole of this district and dividing it up into areas corresponding with various water supplies it is shown that there is not the slightest connection between them. On the other hand, it appears that those districts that have got the purest water supply are those which happen to have the highest mortality from typhoid fever. There is no doubt these districts were urged to get purer water on account of the prevalence of typhoid fever, thinking the water supply had something to do with its prevalence, but personally I am of opinion that the water supply has got little or no connection in this part of the county with the disease. Then comes the question whether it may not be due to this extensive quantity of mud being exposed and covered from time to time with sewage, the discharge of raw sewage on to it, or whether it is due to some other factor, and all I can say is that we have the fact that in these positions where there is a large expanse of foreshore flooded from time to time with sewage, we have the largest amount of typhoid fever. I cannot assert that there is any connection between the two. It did strike me that the experiments which are now well known, made by the Italian Alessi, showed that if you kept animals in places where they were exposed to emanations from sewage, and afterwards infected them with typhoid fever, from 90 to 100 per cent. of them died from the disease, whereas the same number of controlled animals kept in boxes exposed to pure air and then infected with the typhoid bacillus, not one of them died. It seemed therefore that the mere exposure to the emanations from sewage rendered the system more susceptible to an attack of typhoid fever.

8852. It would not affect the case rate, would it?—The case rate? They could not die from typhoid fever unless they suffered from it.

8853. It might increase the mortality—it would not increase the case rate?—It would increase the case rate *pari passu* with the mortality, because, as a rule, 15 to 20 per cent. of those attacked die from typhoid fever.

8854. The experiments only showed that when the organism was introduced the animal suffered more from it?—I think not.

8855. It did not show that it was more susceptible to receive the disease. I do not think Alessi's experiments went so far as that?—Those animals which were not submitted to the emanations did not contract the disease.

8856. They were all given typhoid fever, were they not?—No; I think you will find that was not the case.

8857. They were rabbits, were they not—rabbits and guinea-pigs?—Rabbits and guinea-pigs and white rats.

8858. (*Chairman.*) Do you know of any cases of typhoid fever in animals other than human beings?—No, I do not. That is a subject that has highly interested me, and on which I have always been on the look-out for anything definite. There have been statements in American journals, and, I think, in Canadian ones, that animals have suffered from a disease which is not distinguishable from typhoid fever, but I know of no proof whatever of any animal suffering from it.

(*Sir Michael Foster.*) It was the increase of the effects of the inoculation after the treatment by the sewer gas.

8859. (*Mr. Power.*) It was an extra susceptibility, or a more virulent attack after sewer gas than the animal would have had, but I do not remember the full facts?—Possibly, I cannot give you the words. I think that those that were submitted to the emanations and inoculated, were attacked with typhoid fever, or were attacked with something which caused their death, whereas the others which were not so exposed were not affected. However, I will look that up, to make absolutely certain.

8860. (*Sir Michael Foster.*) Quite so, that would only in any case, I mean, affect the mortality?—Yes, it means, as I take it, that people who are subjected to the emanations from sewage would be more likely to contract the disease, and therefore in such districts you would have a larger proportion of cases.

8861. Was it not simply that when the disease was introduced into these animals they suffered more from it?—I think it was that the animals that were kept in a perfectly healthy condition did not suffer at all.

8862. (*Mr. Power.*) All the animals that were not subjected to the gas?—Yes.

8863. Surely they are all susceptible to inoculation of the enteric fever bacillus; were they guinea pigs?—Under certain conditions. Of course, we cannot be sure, but there is some justification for inferring because sewer air has a certain effect on rabbits and guinea-pigs it may have the same effect on man; it simply raises a presumption that there may be a possible connection between the emanations from polluted mud and the prevalence of typhoid fever near. The next point raised is whether some of the excessive prevalence may not be due to the eating of shell fish picked up on the sewage polluted foreshore, and in my county we have had a good many small outbreaks which have been attributed to the eating of shell fish picked up on the sewage-polluted foreshore near the Thames mouth. I was first led to suspect there was some connection between contaminated shell fish and typhoid in 1894, when I had three successive cases of typhoid at Burnham. The Burnham sewage practically untreated ran into the river just below the town, and immediately above and below there are the oyster layings. These men had been working near those layings. In connection with those I could not find anything else excepting the eating of the shell fish that would account for the disease. From that time I was constantly on the look-out for anything of the kind. Earlier than that even I came across cases of people who had been down to Southend for one day and about three weeks after they have returned home had suffered from typhoid fever; that is a well-known fact, because nearly every medical officer in the county has had cases at one time or another, and a few years ago especially I had many letters from medical officers in London stating that they had got patients suffering from typhoid fever, who had been down to Southend about three weeks before, and suggesting that there was some connection be-

tween the two. It certainly was singular that these people should go down there and be there for a few hours and contract the disease. I remember very well a policeman, a hale, strong, hearty man, who went down to Southend, and about three weeks afterwards he succumbed to the disease, and I found he had been eating these cheap oysters which they can get there for very little, and I have a very strong suspicion that a good deal of typhoid fever which has occurred amongst the people who visit there has been due to their having eaten shell fish while they were at Southend. Then in 1895 the Medical Officer of Southend referred to this in his annual report. He recorded five cases which he attributed to the people having eaten oysters which had been taken from the foreshore. In 1897 the Medical Officer for Colchester referred to four cases which he attributed to eating oysters from the Brightlingsea layings which at that time were seriously exposed to pollution. I visited the pit from which these oysters had been taken, and found that every tide that came up brought a certain amount of sewage actually into the pit. The Medical Officer for the Tendring District had, I think, seven cases at St. Osyth. All these persons had eaten oysters which had been brought from Brightlingsea by a salesman, a hawker who comes round every night from Brightlingsea to the villages around. There were several cases there, every one of whom had had some of these cheap oysters just about the time that they became infected by the fever.

8864. (*Mr. Power.*) At that time the condition of the oysters in Brightlingsea was about as bad as anywhere in your county, the sewage cast on the foreshore going direct into the pits and out again?—No, not direct into the pits, but on to the foreshore and afterwards into the pits. Every time the tide came up it went with the tide into the pits; there could not be any question about that.

8865. (*Sir Michael Foster.*) Did you examine any of the oysters?—Yes, I did. I do not remember that I made anything out of them at that time beyond detecting the presence of bacillus *coli*; I did very little at them then. I have tried a great many times to detect the typhoid bacillus in the presence of B. coli, and I have not been successful; one has not enough leisure.

8866. (*Mr. Power.*) Did you make any estimate of the water as to the proportion of sewage to sea water in which the oysters were steeped?—No.

8867. It might have been a very large proportion of it sewage?—I do not think so because the sewage was coming in from a number of very small drains; it was not coming in all at one place. Some of these places like Brightlingsea had no water supply at that time and only a small portion of the houses were connected with sewers. At any time there was not a large quantity of sewage going down. I never saw more than perhaps the thickness of two fingers going down that drain, so that the proportion could not be large.

8868. But it would trickle in at low water?—No, it came down by the side of the pit, and when the tide came up and reached the pit some of it must have mixed with the sea water and got in with it.

8869. On the flood tide you think it went in?—Yes. Again I find in 1898 that the Medical Officer for Southend extends his views rather and includes amongst shell-fish which have probably caused typhoid fever both cockles and mussels. Cockles are very plentiful round the coast here and are picked up. Children sometimes eat them raw. As a rule they are submitted to a process of so-called boiling which I know from my own experiments does not anything like sterilize them, but I will refer to that again. In 1899 the Medical Officer for Clacton reported five cases which he attributed to the consumption of cockles, and these cockles it was found came from the Orwell near the Ipswich sewers, so there was every probability of their being infected. Then in 1899 I had a series of cases at Heybridge Basin. That is up the River Blackwater near the town of Maldon. There was a number of undoubted cases here between April and August which did not seem in any way to be connected together. There did not seem to be any possibility of one family having affected another. The water did not seem to have anything to do with it because they got water from different pumps; but what I did find was that every one of the families had been eating cockles which had been brought up from a little lower down, picked up by some of the local people from the mud exposed. These cockles were picked up and brought into the hamlet and sold at a cheap rate. In connection therewith I enquired how they were cooked, and I found that a pan is nearly filled with the cockles and some of the people put a little water in; others do not. The pan is placed over the fire for a little time and the steam which is generated causes no doubt the death of the cockle and then the shell flies open. If they steam them too much it is makes them tough, and people do not care for them; therefore they are just steamed until the shells begin to open. If now you examine the shells you will find many of the cockles are almost semi-transparent. If you put them into a sterilizer to sterilize them you are bound to make them perfectly opaque and quite tough. The result is that sterilization is not anything near complete. If you take off some of the cockles from the upper layer in the pans you find that the liquid simply swarms with bacteria. You can inoculate broth or gelatine or any other media and obtain an abundant growth, showing that the process of steaming so far as it is carried on does not sterilize the cockles.

8870. And were experiments carried on in the same way with winkles?—In the same way we made no experiments with winkles. At that time cockles only were suspected. I think you would have to put water in with the winkles. The cockles always have a certain amount of liquid in the shells, which appears to be sufficient for steaming them, but the winkles have not. I believe the winkles are done in exactly the same way but a little water is put in the bottom of the pan. Later on in the year there was an outbreak of typhoid fever at Shoeburyness, just at the mouth of the Thames, and this was rather a larger outbreak than anything which I had been previously connected with and in which there was any suspicion of shell-fish. I went over there on several occasions. The medical officer in the first place told me that he suspected shell-fish and I found there that soldiers going down to Shoeburyness received instructions that they were not to pick up shell-fish on account of the alleged danger of contracting typhoid fever, and I found also that the old inhabitants will not eat shell-fish that has been picked up on their own foreshore for the same reason. And the Medical Officer of Health adduced to me a number of instances in which he had reason to suspect that people who picked up cockles had contracted typhoid fever. For that reason I made very careful inquiries into this outbreak and the results are given in a paper which I sent I think to the "British Medical Journal," and a copy of which has been sent to each member of the Commission. Of course it is almost impossible to prove that nothing else could have caused the typhoid in this instance, but here was the fact that the water supply was derived from a source quite without suspicion, that it was used by the whole of the parish whereas the typhoid cases were confined to one block of houses. I searched for local nuisances and for possible pollution of the subsoil, but I found that these were comparatively new houses. They had been built upon what had been meadow land, it was not filled in ground, and the drainage arrangements were probably as good or better than I had ever seen in any houses of that character. The district having become urban had got a surveyor and whatever houses were being built, the drains were put down to his satifaction. We tested them, and found them all quite satisfactory. It was no question of emanations from the drains which could have either caused the disease or produced an increased susceptibility. Those houses were rather better class cottages and when the person who had built them got them completed he found that he could not get the kind of tenants that he wished, and he therefore had to let them to anybody who would take them. There is a constant interchange of population here, people coming in for the brickmaking. It is a considerable industry. Ultimately the owner had to let most of the cottages to these brickies. One man would take a cottage and let two or three rooms to another family. They perhaps stay a month or two and then again someone else comes in. There is a constant change of people in them. Instead of being tenanted as they should be from their position by the best and most respectable labourers in the place, they prove to be the worst and the dirtiest. There is one thing which seemed to apply to every case, that was that they ate cockles, not only occasionally but almost every day. They are a most improvident lot of people. They found they could get a good meal by sending their children on to the sands, if you like to call them sands, picking up cockles. The children could go out and

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bring a quantity home, therefore at little expense they could get a meal and have left a little more for drink. Nothing else was common to all. With the exception of the tenants in that end house, they were all of the brickie character and all of them had had cockles and in considerable quantities. There was one house in which the woman insisted that neither she nor her children had ever had any cockles. This seemed against the theory that cockles had caused the disease unless it was that they had been infected by some of the other people. On the second visit to that house the woman told me that she remembered distinctly, as one of her children reminded her, that on a certain day which she was able approximately to fix, they had received some cooked cockles from their neighbours next door, and that was the only time she asserts that they had cockles, but that was about the very time when they had become infected. Then in certain houses there were people who did not eat cockles, one or two that I came across said that they knew or suspected that there was a danger in eating them, therefore they never touched them. These people escaped. It only affected those who had eaten cockles. The conclusion I came to after summarising the whole of the evidence I was able to obtain was that the most probable cause was the consumption of these cockles which had been gathered on the foreshore. These cockles I did examine and I found both the bacillus coli and bacillus enteritidis sporogenes, and I communicated with the Local Government Board. At the Board's request I sent some of the cockles to Professor Klein. I also obtained for Professor Klein a map showing where the cockles had been picked and the position of the sewer outfalls. Unfortunately I did not keep a copy of that and Professor Klein has not returned it to me.

8871. At Shoeburyness, you are speaking of?—At Shoeburyness, yes. During recent years, of course, great improvements have been made in the disposal of the sewage from many of these districts, and in other cases improvements are shortly to be carried out; but I have found that where the sewage, even raw sewage, is discharged in properly selected positions, and at suitable states of the tide, that no nuisance arises, so far as we can observe, that is to say, we neither see the sewage coming back towards the place nor have we any emanations or complaints as to odours arising from the sewage, and, of course, if there is nothing in this view that the simple pollution of the foreshore with sewage is dangerous to health, I do not see any reason that there should be considered to be any danger arising from the casting of sewage on to the foreshore—that is, in suitable places. If, on the other hand, there is anything in this possibility of emanations (although they may not be obvious to the senses) increasing the susceptibility to typhoid fever, it would raise the question, in any case where there is an expanse of mud like there is round here, whether it is not dangerous to cast sewage on to it. I have got here, "I am therefore of opinion that crude sewage may be discharged into tidal rivers and estuaries provided the volume of water in such rivers and estuaries at all times very greatly exceeds the volume of the sewage discharged therein. But that where there are large expanses of mud flats alternately covered by the sewage-polluted water and exposed to air, there is probably a danger to health, although no obvious nuisance may be caused." That is as much as I can say with reference to that subject.

8872. Have you formed any opinion as to the proportion of sewage to the volume of sea water that becomes inconvenient or dangerous?—No, but it must be very considerable.

8873. One per cent.?—One per cent. or less.

8874. Or more?—I do not know, I should think probably that if you could get it to one per cent. that you would be free from any risk of nuisance. In the tidal Blackwater, where the sewage of Maldon and the sewage of Heybridge enters, and at Burnham, on the Crouch, the whole of the sewage would never amount to anything like one per cent.

8875. Burnham, and where did you say?—Burnham and Heybridge and Maldon. Those are the three populous places on the Crouch and Blackwater, but the sewage of any of these places would never be anything like one per cent. of the rivers.

8876. (*Sir Michael Foster.*) Not even in summer?—Not even in summer. No, but when you get up the Colne, past Brightlingsea, the sewage will certainly be more than one per cent. of the river water. Beyond Brightlingsea, the Colne narrows rapidly, and at low tide becomes comparatively a small stream beyond Wyvenhoe. The Colne receives the partially-treated sewage of Colchester, the raw sewage of Wyvenhoe and Rowhedge, and the partly-treated sewage of Brightlingsea; and we do get complaints as to the smells arising from that river during the summer time, but in this case the sewage of Colchester, with a population of something like 50,000, forms rather a considerable portion of the whole flow of the river, especially when the tide is down.

8877. (*Mr. Power.*) Is that raw sewage or is it treated?—It is treated with lime at first. Brightlingsea sewage is now treated, although it was not till last year.

8878. What proportion would the sewage bear to the sea water at extreme low water?—Half of it.

8879. Half of it? 50 per cent.?—It varies very much from what I have seen at Wyvenhoe at low water. Sometimes you can almost walk across, only wetting the bottom of your shoes; at other times at low water it may be nearly a foot deep, so that at low water in the river it varies very considerably.

8880. Is the Colchester sewage discharged at all states of the tide?—I believe it is discharged continuously, as far as I can remember; of course, they are now going in for an entirely different scheme.

8881. They have settled on a scheme have they?—Yes, and I believe it is before your Board at the present time, or has been sanctioned by them, I do not know which.

8882. For bacterial treatment?—I think it is bacterial treatment, to supplement their present treatment.

8883. Their present treatment is a precipitation treatment?—Yes, of course Colchester is naturally very jealous of its river, and has made so many complaints about Brightlingsea and Wyvenhoe, that Brightlingsea and Wyvenhoe have said in retaliation, "Well, you are compelling us to cleanse our sewage, why do you not cleanse your own?" Below, it is not so polluted, and there are no complaints. Where we do get complaints is from above. When it becomes mixed with such a large volume of water below Brightlingsea there are no longer any indications of it. Some time ago I did take samples of the river water above and below Brightlingsea, but the pollution below was so small that I could find little indication of it.

8884. Below Brightlingsea?—Above and below, yes. Although much crude sewage or partially-treated sewage is cast into the various estuaries and rivers around the coast here, never until recently have I heard any complaints about it from the owners of shell fish. I think that had any injury arisen to the shell fish itself from casting this raw sewage, or partially-treated sewage into the estuaries, we should undoubtedly have heard of it, but no complaint of any kind was made until after it had been discovered that shell fish might spread typhoid fever. Then only the scare occurred among the oyster merchants.

8885. (*Chairman.*) When was that discovery made, do you know?—1895, I think it was—1894 or 1895.

8886. (*Mr. Power.*) You mean at the Wesleyan College?—At the college, yes.

8887. (*Chairman.*) Then before that time, was there no suspicion that oysters could convey typhoid fever?—No, there was not. I had never even seen it hinted anywhere.

8888. And do you know anything about whether typhoid fever has increased of late years in the county?—I do not think it has; no, my figures do not show that typhoid fever is on the increase.

8889. (*Mr. Power.*) In 1894, at the Wesleyan College, Connecticut, October, 1894?—Yes, 1894.

8890. (*Chairman.*) Going back 30 or 40 years, do you suppose there was as much typhoid fever then as there is now?—When you get back that length of time the statistics begin to be unreliable. 30 or 40 years ago this district was very malarious, all this portion of Essex round the coast and especially that portion bordering on the Thames, and it is quite certain that the fevers, malarial, and typhoid, were not separately recognised. Everything then was put down to fever.

8891. They were not distinguished?—No, only a small proportion of those would be typhoid fever. It is only within comparatively recent years that one has diagnosed that disease with sufficient certainty to have been

able to keep the statistics separate. Another point that was raised was with reference to discharging into tidal waters effluents which, if judged from the chemical standards alone, are satisfactory, but which contain a large number of bacteria common to sewage. That raises the question in a measure of the modern systems of sewage treatment, because the only ways in which the sewage can be treated so that it practically contains all the sewage organisms, and yet is considered to be good chemically, I think are those in which the sewage has been submitted to bacterial treatment. I have been more interested in the question in connection with water supplies than with sewage, and for some time, now, when examining sewage effluents from any source, if we get a particularly good one chemically, we mix it with sterilised water, and see to what extent we have to dilute it before we cease to recognise it. That is how far we have to dilute it before we can cease to detect the enteritidis sporogenes or the bacillus coli. All these bacterially-treated effluents contain most of the organisms of raw sewage from which they are produced. I think the reduction rarely comes to 50 per cent.

8892. (*Mr. Power.*) The bacillus coli?—Therefore, as you get millions of them in a cubic centimetre of sewage, you still get millions of them in the effluent, which chemically is quite satisfactory. The impression, therefore, that I have is this, that, so far as shell fish is concerned, such an effluent is almost as dangerous as the raw sewage itself. In some respects it may probably be more so. I have got here sewage which has been submitted to bacterial treatment by passing through septic tanks and through coke beds, which, although non-putrescent and chemically of a satisfactory quality, yet contains nearly as many organisms as the crude sewage. These organisms are probably the same as those that are in the crude sewage, at least I have always found therein the coli bacillus and the bacillus enteritidis sporogenes in large numbers. I regard this effluent as being as dangerous as the evil smelling ones, or as the raw sewage. So far as shell fish pollution is concerned, these effluents being not nearly so likely to cause a nuisance, their dangerous character may for this reason be overlooked.

8893. Do you think they are as virulent in the effluent as in the raw sewage?—Upon that question I have not the slightest evidence to offer, and I do not see how we can get it for many years to come. Of course, it is a serious matter. It must affect certain districts in Essex where the sewage goes on to the foreshore. It has long been a question what should be done with the sewage before it is allowed to be discharged. If you submit it to bacterial treatment you certainly purify it to this extent, that if it gets on to the foreshore it will cause no nuisance from decomposition, you will get no offensive smells from it, but so far as I know we have not the slightest reason to believe that there is any less danger to the shell fish that may be exposed to it. It is a subject which I think will have to be investigated in some way. If it could be settled it would be a very important point.

8894. Have you any suggestion as to dealing with such effluents to prevent their deleterious effect by reason of their containing those organisms?—The only suggestion is that it should be carried out to sea sufficiently far to get very largely diluted, or if in a tidal river that it should be cast into it at such a point as to ensure that it will always get diluted to a certain amount, say, 1 per cent. In any case it should be taken right away below the low water point, and discharged at such a position that it is not likely to come near any shell fish layings, and I think that if you cannot get the sewage away either treated or untreated without affecting the shell fish layings, the shell fish layings should be abandoned.

8895. But you are including now the cockles, which are widespread all over the foreshore?—Yes; these you could prevent being picked for sale, although not by private individuals.

8896. You would have to prohibit gathering cockles within certain areas?—Yes, as is being done at Southend.

8897. Not from artificial layings?—I think they have got bye-laws prohibiting anyone picking shell fish on certain portions of the foreshore.

8898. Any shell fish?—Yes, any shell fish.

8899. (*Sir Michael Foster.*) For eating purposes that is to say?—Yes, with regard to cockles there are no artificial layings. I do not know what may be done elsewhere, but towards Leigh they bring up large quantities of cockles and lay them in the bed of the river.

8900. (*Mr. Power.*) In the creek?—Yes, they are not laid there for growth; they are not cultivated you may say.

8901. The vast majority that are collected for market are out of the sands far and wide, are they not?—Yes; then they are brought to a place like Leigh probably, and there stored in the sea water close to the merchantmen's place until such times as they are wanted for market.

8902. And then they are boiled at Leigh?—They are—at Leigh most of them are boiled. To places near Leigh such an enormous number of people, fond of shell fish, comes down from London, that Leigh carries on a large trade in these cockles. They are boiled wholesale for the people, and are taken chiefly to Southend and Shoeburyness, and are sold there. They are sold on plates or put into bottles and pickled. I think if they were pickled with vinegar they would be all right, but it is those which are simply boiled.

8903. (*Sir Michael Foster.*) Boiled in the way in which you described just now?—That are dangerous.

8904. (*Mr. Power.*) Are mussels consumed in the same way by visitors and residents as the cockles?—Yes, but not quite to the same extent as cockles; but there is a very large number of them sold in the summer time at Southend; you will find dozens of people with barrows selling oysters in some cases, but all of them cockles and mussels. Three mussels for a penny, I think, and perhaps 20 or 30 cockles for a penny. They are sold already boiled and put on to these plates; the trade in them is something enormous.

8905. (*Chairman.*) Have you taken a great many analyses of these effluents?—The sewage effluents as they go into the creeks?

8906. Yes; when you say you always find the bacillus coli and the enteritidis have you taken a great many analyses?—Merely to ascertain the presence of those organisms we have done hundreds. Since Professor Klein, some three or four years ago, in a report which was prepared for the Local Government Board, showed that bacillus enteritidis could be discovered in a certain way, and that it was always present in the London sewage, I have regarded it as being probably a way in which I could distinguish between a contaminated water and one which was not contaminated. There is no doubt there are numbers of waters which by chemical analysis we cannot say are absolutely free from contamination, and I have been constantly working with the object of finding some method by which we could detect a slight amount of contamination. Many raw sewages you may dilute with 1,000 of pure water, and then by chemical analysis you could not say that it was sewage contaminated, but by bacteriological examination you could detect it to a certainty, even when further diluted, simply by searching for bacillus coli and bacillus enteritidis.

8907. Did you ever consider the question of sterilising these effluents?—Yes, I have; and I have experimented with it also, and I came to the conclusion that there were only two ways of doing it which were at all likely to be practicable, and one was by adding lime in rather considerable excess 60 to 70 grains per gallon, and the other was by adding from 15 to 20 grains of chlorinated lime. I am not sure which is the better way.

8908. Did you try any experiments yourself?—Yes, we are trying on a large scale at the Ilford works with chlorinated lime, and their effluent, so far as we can manage it, is dosed with from 10 to 20 grains of chlorinated lime per gallon, and generally is nearly sterile.

8909. You put the lime into the effluent?—Yes, as it flows from the works there is a large tub into which chloride of lime is put, a certain quantity of water mixed with it, and then the solution is allowed to dribble into the effluent. It then goes down, I should think a mile, in the close culvert, and then gets into the river; indeed, at the end of the time it is thoroughly mixed, and when we get a sample there after receiving this chloride of lime, we find that it is practically sterile.

8910. (*Sir Michael Foster.*) Free from spores of enteritidis?—Not always; no, I am afraid that that is where it would break down, but it is so difficult to be

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sure that we have got any exact quantity of chloride of lime, and I have not tried the experiment with the spores of enteritidis taking definite quantities of sewage and definite quantities of chloride of lime.

8911. The coli was killed?—The coli was killed.

8912. All?—Well, we generally take for coli 1 c.c. of the effluent and put that into about 10 c.c. of phenol broth, and incubate. It is not destroyed in every case, but in the majority of cases. In some cases for some reason or other, there are quantities of organisms present. Whether it is that it has not got enough chloride of lime in it or not I do not know.

8913. (*Mr. Power.*) But you deal with a whole c.c. in each experiment?—Yes. My object at Ilford was to prevent nuisance arising from the smell; it was not really to sterilise it, but I found, contrary to what I expected, I had not only destroyed the smell but when the sewage was put into the incubators and kept—we often keep it for weeks—that the sewage did not acquire any odour again. I quite expected that the chlorine would disappear, and the sewage would then putrefy. To my surprise it did not. Then I made further experiments, and I found that it was practically sterile.

8914. (*Professor Ramsay.*) Have you made trial of any other steriliser?—We tried permanganate of potash. I believe these are all. You see you are limited so by the cost. There is practically only permanganate and lime, and chlorinated lime that I think would be available.

8915. (*Mr. Power.*) Did you try phenyl?—No, I did not try phenyl. I am afraid at present that that is out of the question. I never thought of it, although using it constantly. Even to get 1 in 10,000 phenyl would be a very expensive matter.

8916. Expensive?—If you are treating 1,000,000 gallons of sewage a day.

8917. (*Chairman.*) Would the lime be costly?—The lime comes out the cheapest, but the objection to it is chiefly, that it produces such a large amount of sludge. Then you have got the sludge to dispose of. I do not know if you were taking that out to sea, whether there would be much objection to it.

8918. Would you get much sludge if you only added lime to the purified effluent?—Lime to the purified effluent.

8919. Yes.—No.

8920. I am speaking of the purified effluent.—Oh! I was thinking that you referred to the raw sewage.

8921. No, I was asking you about sterilising the effluent in which the coli appeared?—Yes, well that is a different thing; I believe that that would be successful.

8922. You think lime would be successful?—I think so.

8923. And do you think it would be costly?—You see I am not quite sure whether you would have to add such a large quantity. It never struck me to add the lime to an apparently good effluent. In the experiments which I made the addition of lime was to the raw sewage or a foul effluent.

8924. I beg your pardon, I thought you meant that you had experimented with the lime in order to kill the coli?—No, no; with an effluent which was unsatisfactory chemically. The effluents that our experiments have been made with at Ilford is most unsatisfactory chemically, it is practically raw sewage.

8925. You have never tried with a purified effluent?—No.

8926. But if the lime could destroy it in raw sewage, I presume you would imagine it would destroy it in the effluent?—I think so. I should say in that case you would not have the slightest difficulty; you would get no deposit formed, and you would get the sterilizing action.

8927. (*Sir Michael Foster.*) You have said they eat a good deal of cockles and other shell fish at Leigh and Southend and Shoeburyness?—Visitors.

8928. Yes?—Yes.

8929. At Rochford, too?—In the Rochford district.

8930. I am taking your numbers?—I do not think you would find in the Rochford district itself, where visitors have not access, that there is any shellfish eaten at all.

8931. I was wondering how far eating shell fish would account for the high case rate and death rate?—It would only do it partly. Where you have no visitors in the other parts of the Orsett and Rochford district, it certainly would not account for it.

8932. (*Dr. Russell.*) Disease amongst visitors would not come into the category of the product of Essex?—No, many of the cases do not, there is only a certain portion that do. There is not the slightest doubt that at one time there were more people contracted the disease in this district, and were notified away from the district, than in the district itself.

8933. So that the measure of the prevalence of enteric fever in Essex or these parts of it is no measure of the injury caused by these shell fish?—Not the least.

8934. (*Sir Michael Foster.*) But you are inclined to think that in Shoeburyness, the high case rate and death rate from typhoid fever is partly due to eating cockles?—I think in part it must be, yes.

8935. These brickies as you call them, lived under insanitary conditions elsewhere before they came to Shoeburyness?—Oh! no doubt.

8936. So that they might have brought it with them?—Well, one family might have brought it into the block of houses, but, if I remember rightly, you will find the family that was first infected was not one that had just come in, it had been in some time. And there was another case which had occurred just previously which the medical officer—I did not see it—attributed to shell fish. It was the case of a resident who had been in the district some time, and yet after crossing the sands here he had been in the habit of picking up either winkles or cockles and eating them. That was the only cause to which he could attribute it. Of course, they work, too, with very filthy material. The soft core that comes down for burning in making the bricks is very filthy, and, of course, that is handled a good deal. They are not particularly cleanly in their habits. One thought there might be infection in that way, but inquiries made amongst the other brickies showed that although they were using the same material in the same way there was no typhoid fever.

8937. (*Professor Ramsay.*) You make a statement about the standard of the Thames Conservancy, indirectly?—In connection with Ilford.

8938. Ilford satisfies a standard of the Thames Conservancy. What is that standard?—When I say satisfied them, I know that they took samples and were satisfied with them. I took samples about the same time, therefore I judge what their standard is, but when I was there some time ago in connection with this Ilford work they gave me the figures of certain effluents which were satisfactory and certain which were not, but they declined to say what their standard was. But still it was curious in this case that while they were using chemical precipitants the sewage went into the river in a most noxious condition; it stank horribly, yet they were satisfied with it, but when they turned it in after it had been chlorinated until there was no smell, except the very faintest smell of chlorine in it, and it would keep apparently for an indefinite period without smelling, though it contained rather a higher amount of organic ammonia, they wrote to say it was not satisfactory, so that the Ilford people are between the devil and the deep sea. If they send it into the river in a smelling condition I am down upon them as causing a nuisance; if they send it in such a condition that it does not smell and satisfies me then it offends the Thames Conservancy.

8939. Have you met the Thames Conservancy on the matter?—Yes.

8940. Is there no means of adjustment?—Well, the means of adjustment I think are these, that Ilford now is constructing a large main outfall sewer, which will bring their sewage down to the Thames, and then, instead of sending it into Barking Creek or the River Roding, it will go right into the Thames, and I think then the Conservancy will not require such a high standard; in fact, I examined some of the sewage taken from the northern outfall works, London works, and some taken from the Ilford works, and there was very little difference in them; so that, no doubt, if they expect the same standard for each they will let the Ilford sewage go in without any further treatment, and I believe that is the real reason why the Thames Conservancy has taken no further action. Ilford are doing all that they possibly can in the time, and these works the being rapidly pushed forward.

8941. Is it not necessary that the typhoid fever should come from somewhere. It is a ridiculous question to

ask; the germs must be there?—It may be a ridiculous question to ask, but it is one sanitarians are every day putting to themselves. It seems to be difficult to answer. Of course, the germ cannot arise *de novo*. We believe not. But whether it may be that it lies dormant till something is disturbed, or whether it must be introduced by some individual I cannot say.

8942. Would it require persons susceptible by exposure to sewage?—In the rural districts it is most puzzling to account for outbreaks of typhoid fever. From time to time we find outbreaks occur in villages where there has been nothing of the kind for years, and where the most careful examination fails to reveal any way in which the microbe can have been introduced.

8943. (*Mr. Power.*) Or to prove the person has been out of the village?—Or to prove the person has been out of the village?

8944. I mean the particular person attacked?—Yes, quite so.

8945. (*Professor Ramsay.*) What tests do you generally use in judging of the purity of a sewage effluent?—Chemical or bacteriological.

8946. Chemical first?—Practically there is only chemical. There is no bacteriological standard. I think the standard that I have generally taken is in parts per 100,000, 0·1 of albuminoid ammonia, and 1·0 of oxygen absorbed. If you get that it is fairly satisfactory, but even then the effluent will often be offensive.

8947. You do not regard that as absolutely satisfactory?—Well, it depends where it is to be put. Into a stream I do not mind at all if it contains a little more organic matter if it has been treated in such a way as to be non-putrescible. I lay much more stress on the non-putrescibility of an effluent than on the chemical analysis of it.

8948. You always test the putrescibility?—Yes, we always put it in the incubator for three days.

8949. Do you test the oxygen in the water?—No. We have not done that recently. There is a process known by my name. At one time I did a very large number, because I thought it was going to help me in distinguishing between polluted and unpolluted waters. I carried it on for sufficient length of time to say it was valueless for the purpose. Since then I have rarely used it.

8950. But for sewage effluents?—For sewage effluents I do not know whether it is really necessary. You may get interesting information from it, but if you find an effluent is non-putrescible, practically it shows you that it is fairly well oxygenated.

8951. Certainly; but if it is not oxygenated, does it not rather point to its being putrescible?—Well, it would be a quicker way very likely to determine the free oxygen in it than put it in the incubator and wait two or three days, but the one I think is very much more reliable than the other. Of course, one would not be inclined to regard an effluent as satisfactory if it was not fairly well oxygenated, but even if you found afterwards that by keeping, it still remains perfectly sweet, I think it would simply mean that it was not oxygenated, because it had not had an opportunity of absorbing oxygen.

8952. Quite so. The object, of course, of putting these questions is to try and find out whether there is any plan by which a manager or workman on a small sewage works could judge approximately of the extent of purification?—I am afraid there is no very simple method by which it can be done unless it is taking the degree of oxygenation of the effluent.

8953. Something of the kind?—Yes, because if he has to wait two or three days to find whether the effluent will turn putrid or not, that is altogether out of the question. But, as a rule, I think you will find that if your effluent comes out fairly free from colour and free from odour, it is going to be satisfactory. There is a disappearance of the colour, at the same time that there is a disappearance of the organic matter, and viewing this sewage through a tube of some little length is a very simple and fairly ready means of estimating the degree to which the purification has been carried.

8954. (*Sir Michael Foster.*) At all events it would detect an impure effluent?—Yes; you have no difficulty in telling an impure one.

8955. No, but I mean you might not be quite sure that it was as pure as it appeared, because it was transparent, but if it was not transparent you might be sure that it was impure?—Quite so.

8956. (*Professor Ramsay.*) Would you be favourable to allowing any sewage effluents to pass into a stream that is used for drinking?—Any sewage effluent? Not if I could possibly avoid it, unless we devised some method of treating it different to any with which we are at present acquainted. Even a sewage farm effluent, although at times it may be fairly satisfactory, almost invariably contains a very large number or organisms.

8957. Which may be pathogenic?—Which may be pathogenic. Of course, I believe that if the sewage were simply passed through land in sufficient quantity—that is to say, you do not pass more over the land than perhaps would correspond to a rainfall of 50 inches in the year, I do not see why you should not make the sewage as pure as the ordinary subsoil water. But passing it through in larger quantities danger always arises. I do not see how you could get over that except by taking a larger quantity of land.

8958. But for effluents which are not admitted to streams used for drinking purposes, have you any standard of purity?—I have not, and I think that the non-putrescibility of the sewage should be the standard.

8959. Have you had much experience of the working of Dibdin beds?—Well, we have some of them in Essex, a small number, none of them very large. There are some at Ilford, some at Hornchurch, some at Warley, and we have got some at Writtle, and so on, all on a small scale at the present time.

8960. Do they use septic tanks or not?—At Hornchurch and at Warley they have got septic tanks.

8961. Have you any idea of the relative advantages of the different systems of septic tanks where used and where they are not?—Do you mean between the coarse Dibdin bed?

8962. The coarse Dibdin bed without a septic tank?—I would rather have the coarse Dibdin bed.

8963. Without the septic tank?—The septic tanks undoubtedly fill up.

8964. That is the practical difficulty?—Yes; and then you have to start afresh, and the sludge has to be removed. The coarse beds properly used will go on no doubt for a longer time than a septic tank without being looked to. Of course, elsewhere I have seen these beds, at Sheffield and Manchester and Leeds, and all over the country, and I was speaking from this experience. I have not seen the septic tanks except at Exeter and three places in Essex, and in two of these cases there is no doubt sludge that has to be removed.

8965. Constantly?—I do not know how often, but the Hornchurch one which went on for, I think, about twelve months, and which the man who put it down assured me would never require emptying, there were soon signs of an increasing amount of deposit. Last time I went down I found they had had to empty it, and all the sludge was there on the ground around. It was sludged up.

8966. Was that not because it had been overworked?—No, it could not possibly be, because Hornchurch is only a comparatively small place, and only a small postion of the sewage entered it. It was made to carry the whole sewage of the place.

8967. (*Sir Michael Foster.*) It was only twelve months old?—It was only twelve months old.

8968. (*Professor Ramsay.*) You believe there is better purification without the use of a septic tank?—At the present time I should be very much inclined to favour coarse coke, passing it through that, than passing it through a septic tank.

8969. Have you had any experience of continuous filtration?—Not that is worth anything. We have continuous filtration at Writtle, and it is worthless. Whether it is that we have put too much sewage through it or not I do not know, but the sewage comes out almost as bad as it went in. But still I do not want to damn the continuous system on that account.

8970. Do you attach much weight to the oxygen absorbed test?—I like to have it low; but it usually seems to correspond with the albuminoid ammonia. Of course, we always do both; we do the oxygen absorbed and the albuminoid ammonia in every case, and in making these charts for the Ilford sewage, we examined about four samples a week, and have done for the last eighteen months. The charts I have made from them so

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closely correspond that the one will do in place of the other, if you do not care to do both.

8971. You think it is an advantage?—The albuminoid ammonia is more quickly done.

8972. There is no difficulty in doing them together. If you are dealing with one kind of sewage for a period of months they probably would give you good indications?—They do.

8973. The different tests, "oxygen absorbed" and "albuminoid ammonia" would give results which could be compared?—I think they would be fairly comparable unless there is something peculiar in the nature of the sewage originally. Sewage, of course, does vary. One would not expect to get similar results taking the sewage of Burton-on-Trent and the sewage of Manchester, but if you were treating what might be called a purely domestic sewage, I think the results would be comparative.

8974. (*Dr. Russell.*) I have been looking at this table of the Shoeburyness outbreak, on page 2. Can you tell me what was done to prevent the spread of this outbreak? Were any of these cases removed to hospital?—No; they have not got such a thing in the neighbourhood, so they cannot remove them.

Appendix No. 7.

8975. That is just what I thought. Apart from oysters or anything else, looking at this table a moment it is more like a table that you might get the parallel of in any village where the first cases were allowed to lie at home. I see No. 8, the three secondary cases distributed over five to six weeks after the first case?—No doubt the secondary cases in a great many instances were really secondary, that is derived from the first case in the house.

Appendix No. 7.

8976. And in No. 9 there were six secondary cases distributed over a period of five weeks, and in No. 4 there were three distributed over a fortnight?—Yes.

8977. So that it looks very much like what you would expect among people of that sort if you did not adopt any efficient means of preventing the spread in the first case?—Oh, yes, there is a possibility that it may have been infection from house to house, but I was inclined to think that that did not account for all the facts.

8978. Have you had the class of case which is much more convincing than this where cases of enteric fever were reported, we will say, from all points of the compass, half a dozen cases, one London, another in Liverpool, and distributed about the country?—In connection with cockles?

8979. And they had nothing in common, but at one period of time they took part in an excursion where oysters or cockles or something of that kind was a part of the entertainment. Have you had any case of that kind?—Not in connection with cockles, but we had one in connection with oysters in which the cases occurred at various parts of Colchester, and I think some at Ipswich.

8980. I am a thorough believer in the medium of oysters and shell fish; they are a most dangerous medium of the distribution of infection, but the convincing case is a case of that kind such as a county ball which I know of?—Oh, yes.

8981. Where the ladies and gentlemen took ill simultaneously all over the country and on the Continent, and where the only connection is that they came together at this ball, and they all partook of oysters?—You see you are likely to get that sort of thing with oysters, but the character of people who eat cockles is scarcely the same. This class of people, if they did meet together at any social function, I do not think cockles would form a portion of their menu: They are more things which are partaken of at odd times.

8982. But the interest to my mind is this, that it establishes those shell fish as a *vera causa*?—Oh, yes, the proof from which would be very much greater than anything that could be adduced in this way, no doubt

8983. And they produce enteric fever under circumstances which are very difficult to detect?—Quite so.

8984. To demonstrate in a satisfactory way?—Yes.

8985. But that does not diminish the reality of the effect which they may have in those sporadic cases that to each several observer cannot be accounted for at all, but when you focus the information the demonstration is conclusive?—No; the only reason why this was published was the fact that I thought that very probably there was some connection. If cases of this kind are published other people will pay attention to the subject, and in that way sooner or later we shall be able to establish actually whether there is any real connection between such things as mussels and cockles and the dissemination of typhoid fever.

8986. I see you mention as one of the facts in the case that one milk supply was impure, but it was only used in two out of the seven houses infected?—Yes.

8987. What was the nature of the impurity?—Well, it was undoubtedly mixed with water, and the water was undoubtedly polluted. We found both coli and enteritidis in it, and the inspector went to the dairy and he found they were using water in the dairy which came from a ditch or pond of a most unsatisfactory character.

8988. That, of course, is another weak element in the evidence?—But that only applied to two houses. The other people denied that they ever had milk from this particular person.

8989. But you have often investigated milk epidemics of an undoubted character; at least, you have had experience of that kind?—Yes.

8990. And it is constantly one's experience that there is a fringe of people who say they had never touched the milk, but they had got the enteric fever?—Yes, but in this case the fringe would be larger than the material: if it had been the other way about it would have been much stronger.

8991. Was this milk used anywhere else?—Yes, it was used in other parts of the town where there was no typhoid fever.

8992. I merely wanted to know as this would be a very frail case to raise any agitation upon?—It simply gives the facts so far as I was able to record them in the hope that other people would be alive to the possibility of cockles producing typhoid fever, and would make inquiries accordingly. In my county now every case that occurs we make inquiries about all kinds of shell fish, as I think I mentioned, the Medical Officer for Southend in his last report thinks it is possible that several cases of typhoid that had occurred there were due to eating these cockles, at any rate he could not find any other cause; but it is by the multiplication of instances of this kind that we may possibly in the long run arrive at the truth.

8993. Then is there no such thing as the hospital treatment of enteric fever in Essex?—At Southend there is, but in districts round Southend there is not, but a hospital is being built, and probably in twelve months it will be ready, and probably things will be much better.

8994. I am afraid that is another weak element in the argument. Essex is distinguished in that way as well as by partaking of cockles?—Then, unfortunately, there has been a great deal of difficulty in educating the various authorities in Essex to the necessity for isolation hospitals.

8995. (*Mr. Killick.*) You have spoken, I think, altogether, Dr. Thresh, about effluents that discharge into the sea?—Into the sea or tidal waters.

8996. The effluents discharging into the streams in Essex—has there much been done—sewage effluents?—Yes, up the river Roding, which is the river which runs through the most populous part of Essex, every district now is going in for a bacterial system of treatment.

8997. Is that under pressure from the County Council?—Yes; we have not pressed them as to what system they should adopt, but the constant complaints about the condition of this river led me to take samples periodically of the effluents that they were sending in, which showed that they were of a most unsatisfactory character. The result was continued correspondence between the District Councils and the County Council, and each one of them has got out a plan, and I believe some of them (Buckhurst Hill, Wanstead) have been already sanctioned and are in progress, and there are three or four more which I believe are in the hands of the Local Government Board.

8998. You are exercising your powers under the 1868 Act, I suppose?—The Rivers Pollution Act.

8999. Yes, but under the powers that you have as a Sanitary Authority under the 1888 Act?—Oh, yes, certainly.

9000. And are you applying that to the whole county?—Yes, of course, every town in the county is discharging sewage into some of the rivers, and where the effluent is not satisfactory we report it to them We find that some of the worst pollution arises from the larger villages, where they have got no sewage works, but

simply their old road drains, which originally were intended to carry the road water from the villages into the river. They have been converted into sewers, and the household sewage goes in untreated.

9001. Are you putting pressure on the Rural District Council in that case?—Yes, we are. Then comes a difficulty. I have one parish in my mind now with a population of a little over 1,000. I complained of this, and they said, "What would you advise us to do?" "Well," I said, "the best plan is to consult a sanitary engineer." They called in a well-known engineer in London, and he has devised them a scheme, and to carry it out will cost £10,000. They certainly cannot do it.

9002. (*Sir Michael Foster.*) What system has he advised for them, do you know?—He proposes to take in nearly every house in the whole of the parish, and adopt bacterial treatment, and discharge the final effluent into the stream. I do not know quite, as Medical Officer of Health for the county, whether I ought to advise. They invited me over to see those plans, and I thought candidly it was out of the question, a small place like that incurring such expense.

9003. (*Mr. Power.*) Is there a public water supply in this parish?—No, I am pushing them on for a public water supply as well; that is an additional expense.

9004. (*Mr. Killick.*) That is a case in which you will have to do a little bottle holding. The only way to deal with those cases in your experience is just doing as much as you can?—To get what would be considered a complete scheme is very often so expensive that it is beyond the power of the authorities to carry it out; but there is no doubt that the districts themselves are in a great measure to blame. They let things go from bad to worse, instead of trying to make the best of what they have got. They let a man with a house on a detached portion of land run a drain into a ditch or some other road drain, instead of making him dispose of his sewage on that portion of land, and so they go on accentuating nuisances, instead of compelling each tenant in these isolated cases to dispose of his sewage on his own premises.

9005. That is you deal with the individual separate houses. I suppose you complain of those to the local authority?—If it is only minor matters of that kind they come under the cognisance of the Local Medical Officer of Health. As County Medical Officer of Health I am only consulted, or generally have to report upon the larger matters referring to the whole of the parish.

9006. You do not interfere from the county with the small cases of pollution?—If it was a small case of pollution getting down to the river, no doubt we should. We have done in several instances, but, as a rule, drains get combined together into a combined drain before they get down to the river. We have not many instances in which each house runs a drain to the stream; perhaps there will be a group of half a dozen or a dozen houses; these would all combine into one drain, and that drain comes into the stream.

9007. I suppose you have accelerated the progress of the erection of sewage installations since you took action?—Yes, we could have done more if it had not been that we thought things were in such a condition just now that we ought not to press them to do too much, until we feel more certain as to the best system to adopt, especially in those districts where the population is growing so rapidly.

9008. Just for a moment to turn to another subject. You say you have provided a statement of the high death rate in the district in Manchester, through which the much polluted river goes?—Yes.

9009. And you could not prove any increase in the death rate from the polluted state of it?—At that time I was connected with the Manchester and Salford Sanitary Association, and at their request I made an investigation into the high death rate in what was called No. 1 Ancoats. Before starting that I wanted to have an idea of the death rate of the various districts into which Manchester was divided, and it seemed to me at that time that some of the worst districts must be those through which the Irwell flowed, because the condition at that time, if not even now, was vile in the extreme. Taking the figures for ten years, I could not find the slightest indication of any ill effect from the polluted river going through the borough.

9010. You did not make any experiments or inquiries as to the vitality of the people living near the river?—I went into all the districts, and made all sorts of inquiries, but there were many factors which vitiated any conclusion you might draw. One district where I thought from the high death rate the probability was that the river had something to do with it, when I got there I found only the lowest class of people, the rents were so exceedingly low that no one drifted there until they were almost absolutely destitute, or criminal and wanted to hide away from justice. It was a district in which whatever the surroundings had been there would have been a very high mortality. When a man is earning 30s. a week he can afford a good cottage, but when he is in failing health, and only able to earn 25s. a week he, perhaps, economises, and gets a cottage at a little less rent. Still failing in health he gets into something at 1s. or 1s. 6d. a week. At that stage his family is half starved, and he is probably in a half dying condition. There you have a very high mortality, but it has nothing to do with the district.

9011. You could not say in any way that the river caused injury to health?—I spent a good deal of time over it, and discussed it with, I think it was Dr. Ransome, and one or two others who are very much interested in the sanitation of Manchester, and it was resolved not to say a word about it, because there was not a particle of evidence to show it had any effect upon the health of the people.

9012. (*Sir Michael Foster.*) That was the effluvium from the river, I suppose?—Yes.

9013. (*Mr. Killick.*) I remember the case, that was why I asked about it?—Yes.

9014. (*Dr. Russell.*) You came to the same conclusion as the last Royal Commission on Sewage came to. They endeavoured to establish a case founded upon investigation of the health of such as these in the neighbourhood of polluted rivers, and found that the local conditions antagonistic to health were such as to vitiate any conclusions?—There is no doubt that is so.

9015. (*Professor Ramsay.*) Just one question on your last remarks speaking to Mr. Killick; have you any idea about the rural disposal of sewage; would you say that a farmer, for example, could dispose of his own sewage?—A farmer? Yes.

9016. Do you favour the dry closet system or cesspools?—Cesspools and dry closets, if you can get them emptied, and emptied by the authority, and the contents removed, is very likely a satisfactory solution of the difficulty, but, unfortunately, the people will not remove them; they will not empty them; the owners will not, and if the authority steps in, it becomes so expensive that it often is cheaper to lay down a system of sewerage. The parish of Stanford in Essex wanted to avoid sewering. They have a very large number of cesspools, and they bought two of these cesspool emptiers, I forget the name of them, made by someone in Gravesend. It is a huge tank upon wheels; they take it to the cesspool, put down the hose-pipe, pump away, and fill the tank. When that had been going on for some time I went over and inquired into it, and I worked out a little sum in arithmetic for them, which showed them that the cost that they were bearing, in providing the men and the horses, and so on, was more than the interest would be on the provision of a proper sewerage scheme. The result is that they have gone in for a sewage scheme, but being not far from the Thames they do not have to get the high degree of purity necessary in other parts of the county, and therefore their scheme is much cheaper.

9017. What about dry closets?—Dry closets, I think, are excellent where there is a small quantity of garden for them to dispose of the contents upon.

9018. (*Chairman.*) They are the best possible things, I suppose?—Yes; there is no doubt in the country.

9019. I do not know whether you have any particular favour for one form rather than another. Is it better to have a pail or better to have a pit?—I prefer a pail because with a pit you have not the control that you have over the pail. If there is a pail the inspector sees if it is full; an inspector can say something; in the case of a pit there is always a dispute as to whether it is full or not, and when it was removed last and so forth.

9020. A pail is nothing but an additional nuisance when they do not empty it?—No; that is the trouble, but that is not due to the system.

9021. It seems to me the question turns on the habit of the people?—Quite so; and almost everything in connection with sanitation in rural districts turns on the habits of the people. In many places I find that where there is sufficient garden to dispose not only of

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the slops but the contents of the pail closet they will not do either; they will throw all their slops over the hedge into somebody else's ditch; they dig a big hole through which the privy contents can ooze into the same ditch, and they are quite satisfied.

9022. But you are quite satisfied with the pit, provided it is cleaned out?—Yes; oh dear, yes.

9023. (*Mr. Killick.*) The objection to the pail is when pails have to be collected and carried through a populous district?—Oh, there is more objection then. It does not apply in a rural district where you are able to dispose of it near your own premises.

9024. That is the great objection?—In the Maldon district we have made an arrangement whereby a certain amount of land near the cottages has been rendered available to the cottage people for the purpose of disposing of their slops and pail contents. Just now we are arranging with the brewery to have an acre of land at the back of six cottage. There is a little garden in front, but no garden at the back, nothing to discharge upon. Behind there are the four closets, and no proper drains. We have now made an arrangement for an acre of land divided into six parts; the closets will be removed to the far end of the piece of ground, and we shall expect them to attend to the pails, and also dispose of the slops by distributing them over the garden, and in that way I am quite sure that they will get rid of all nuisance. Bearing on that point, we have had lately an outbreak of diphtheria in the parish or hamlet called Howe Street. I went over there, and the conditions were such that I afterwards got some of the members of the District Council to visit with me, and it was a curious fact that every nuisance complained of arose from drains which had been put into the cottages; not a single nuisance was complained of in those houses that had got no drains; where they spread their slops over the ground there was no nuisance; where they had been allowed to put in a little drain and drain it to a ditch there were the complaints.

9025. (*Sir Michael Foster.*) You mean there were the cases?—Not all the cases.

9026. (*Chairman.*) Have you had much experience of sewage farms?—We have several in the county, in some of which I take a good deal of interest.

9027. And have you ever known a case where animals have suffered from feeding on a sewage farm?—I have heard people state that such things have occurred, but when I have inquired at any of these farms I have never heard of anything of the kind occurring. We have several sewage farms—one of about 108 acres at Chelmsford, one of nearly 200 acres at Romford, one at Halstead, one at Bishop Stortford. Bishop Stortford is outside Essex, but the sewage farm is in the county. There are several other very small farms.

THIRTY-THIRD DAY.

Thursday, 9th May, 1901.

PRESENT:

The Right Hon. the Earl of IDDESLEIGH (*Chairman*), *presiding.*

Mr. WILLIAM HENRY POWER, F.R.S.
Major-General CONSTANTINE PHIPPS CAREY, R.E.
Mr. THOMAS WILLIAM KILLICK.
Dr. JAMES BURN RUSSELL.
Mr. CHARLES PHILIP COTTON.

Mr. F. J. WILLIS.

PRESENT ALSO:

Dr. A. C. HOUSTON.

Mr. THOMAS EUSTACE HILL, County Medical Officer, Durham, called; and Examined.

Mr. T. E. Hill.
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9028. (*Chairman.*) You are Dr. Eustace Hill, Medical Officer of the County of Durham?—Yes.

9029. And you have had some experience of cases where sewage or manufacturing refuse has gone into tidal waters?—Yes, especially with regard to the River Wear.

9030. Will you kindly give us your views on the subject?—The River Wear has a tidal length of 10 or 12 miles, and throughout its course it receives a considerable amount of sewage; in particular and in one place it also receives very foul liquid coming from some waste chemical heaps. With regard to the sewage in the upper reaches, there are not any ill-effects apparently, but when you get down towards the mouth 2 or 3 miles up you get the Urban District of Southwick with a population of about 12,000 or 14,000 and the County Borough of Sunderland discharging their crude sewage into the river and undoubtedly there is very considerable pollution, which is particularly evident when the tide is low. The tide when it goes down exposes a considerable amount of river bed, and that is covered for a very considerable depth with a very black and offensive substance. Even in winter time on taking some of that up and smelling it it has a distinct sewage offensive smell, and even in winter time there is a considerable amount of decomposition going on. In summer time no doubt the decomposition is very much greater, and the emanations in my opinion must be objectionable and cause some danger to the health of people living near it and frequenting the river. Then with regard to the manufacturing refuse, that discharges in at Washington Staiths about 7 or 8 miles up the river, and comes from huge heaps of waste chemical refuse, which contain apparently a large amount of sulphide of calcium, which decomposes, giving off sulphuretted hydrogen, and discharges into the river also unpurified. There is a considerable population living immediately on the banks there and the smell even in the houses is perceptible. It was much worse up to a short time ago because the outfall of the liquid was above low water. They have recently carried it below low water and that to some extent mitigates the nuisance but there is no doubt that the nuisance from this must lower the vitality of people living near it, because it is undoubtedly an overpowering and most offensive smell, and there cannot be the slightest doubt that it must be seriously prejudicial to fish life.

9031. (*Mr. Power.*) Is it so objectionable as to induce nausea and vomiting; do you have any general complaint to that extent?—Yes. Some of the people say they have had nausea. I questioned the people on the river's bank and they say they do at times, or rather did, when this was very bad, suffer considerably, and many of them have a particularly unhealthy appearance.

9032. Do you think the emanations are from the river itself or from the foreshore? There is not a very large amount of foreshore uncovered at Sunderland. There it is rather a narrow and deep river,

the Wear, is it not?—No; but I should think there is 25 yards probably, especially on the Southwick side, that is on the north side.

9033. The north side?—And there there are several boat ferries. The working men and other people cross the river from one side to the other, and at low tide they have to walk by wooden platforms right over this. Then in addition the sewers, at Southwick particularly, discharge at the far end of the foreshore and during low water they run in a dirty stream down to the river, which of course is also objectionable. One of the main sewers is close to the gangway at one of the local ferries.

9034. Are the complaints as to this injury to health, this nausea and headache, confined to Southwick, or do they come from Sunderland too?—I should like to point out that this nausea from sulphuretted hydrogen is seven miles up the river, not at Southwick and not at Sunderland, that is quite a separate place.

9035. It is limited to the point at which the liquid discharges?—At which that liquid discharges. There is the parish of Washington Staiths at the discharge, and there is the parish of Cox Green on the other side of the river and the people have complained very strongly of this nuisance.

9036. But you have objectionable emanations from the mud given off within the Borough of Sunderland?—Yes, within the Borough of Sunderland and especially on the Southwick side, in the Urban District of Southwick.

9037. (*Major-General Carey.*) The sewage is not treated at all?—The sewage is not treated at all, no.

9038. Is it discharged on the ebb tide?—It is discharged at all tides.

9039. (*Mr. Power.*) By a number of separate outfalls?—By a number of separate outfalls, yes.

9040. On both sides of the river?—On both sides of the river, yes.

9041. (*Chairman.*) Then will you proceed with your statement?—Then I may say when I was Medical Officer of Health to the Borough of South Shields 10 years ago, we had a frequent cause of complaint with the Mill Dam near the Custom House where one of the main sewers of the town discharged—this is the River Tyne I may say now—into the river and got washed back into a *cul de sac* where the pilots' boats were stowed, and in hot weather there was a very considerable nuisance. No doubt that could have been obviated if the sewer could have been carried further into the river, but it has not been done even up to this time, and the nuisance still exists. But that is with regard to the River Tyne. That is the only experience I have had of any nuisance arising from that river, although of course the pollution is very considerable, but it is a very much bigger river in volume and size than the Wear. I should say that the River Wear Fishery Board have made several complaints to the County Council of the pollutions from this manufacturing refuse at Washington Staiths and of the pollution of the river by sewage.

9042. (*Mr. Power.*) What Board is that?—The Wear Fishery Board.

9043. Do they allege actual damage to fish?—Yes, they allege actual damage to fish.

9044. To salmon, for instance?—I suppose salmon. So far as I am aware they did not specify any particular fish, but only the other day I wrote to the Clerk of that authority again, and he said, "In reply I may say that the Board have several times had cause to complain of the pollution of the river from chemical works and sewerage in the localities you refer to, but recently the pollution has somewhat abated in those parts." But we have had complaints directly from the Wear Fishery Board, and the County Council, I may say, are doing their utmost to prevent the pollution of the river; but, as you know, without the consent of the Local Government Board it is impossible for them to take action with regard to tidal waters. At the present time one of the local authorities in the county, the Chester-le-Street authority, are proposing to discharge a very large outfall sewer into the tidal waters of the Wear very near to this Washington Staiths which I spoke of. We have done our best to prevent it, and we are in communication with the Board of Trade, whose sanction has to be obtained I believe to new outfall works, urging them to prevent this sewage running into the tidal waters without prior purification.

9045. Without any treatment at all?—Without any treatment at all, and there the local authority are endeavouring to get this entirely new outfall for the purpose of draining villages situated three or four miles away from the Wear, into the tidal waters without purification, and the County Council naturally object to that, and as I say we have had complaints from the Wear Fishery Board on the subject. I hope we shall be able to prevent it.

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9046. The Wear Fishery Board are not merely concerned with fish but with shell-fish also; they are not solely salmon conservators?—Salmon conservators and trout.

9047. And trout?—Bull trout are fairly common in the Wear, but there are no oyster beds. They have nothing to do with shell-fish. There is no necessity to deal with that question. I am not sure that there are any other points with regard to these chemical pollutions. The second point upon which my opinion is asked is in regard to effluents that are chemically pure and yet contained the bacteria common to sewage. Well, personally, I do not see any serious harm can result from the discharge into tidal waters of an effluent which is chemically satisfactory, but which contains bacteria common to sewage. The tidal waters are never used for drinking purposes nor for cattle, and as a rule the volume of the tidal water is so great that I cannot imagine that any serious injury to health or damage to fish life would result if the effluents were chemically pure.

9048. (*Chairman.*) But I suppose you would not say that if there were oyster beds within the tidal waters?—Well, there would be possibly a risk, but the evidence, so far, of the existence of the pathogenic organisms in chemically pure effluents is so small and so slight that I am not sure that the question cannot be to some extent disregarded. What I mean to say is, as no doubt you are aware, there is the greatest difficulty in finding we will say, the typhoid fever bacillus in a chemically pure effluent, and in that case if a chemically pure effluent discharged into a very large tidal volume of water I cannot imagine that there would be any very serious risk to any oyster beds.

9049. Are you speaking from your own experience in saying that in a chemically pure effluent there are very few pathogenic organisms?—Recognised pathogenic organisms, yes.

9050. Do you say that from your own experience?—Well, when I say from my own experience, not directly from my own experience, because I am not a bacteriologist, but from my general knowledge of the subject.

9051. (*Mr. Power.*) But they are extremely scarce in the raw sewage, are they not—pathogenic organisms?—Apparently they are; I mean to say they are difficult to find.

9052. But the associate of the enteric fever bacillus, the bacillus coli, is very abundant in many of these effluents?—It is undoubtedly.

9053. Almost as abundunt as in the sewage?—Yes, and I may say in a paper which I delivered a few weeks ago before the Society of Medical Officers of Health I gave vent to the opinion that when chemically pure effluents are discharged into ordinary rivers, especially where there is a possibility of their being used for drinking purposes, the ordinary passing through bacteria contact tanks, for instance, is not satisfactory, and that there should be an additional sand filter or something of that kind, or land. I quite agree with the Local Government Board that where there is any possibility of the water being used for drinking purposes, ordinary artificial filtration, although it is bacterial in action, of the sewage entering it is probably not sufficient.

9054. But you think so far as a tidal water is concerned, and so far as fish apart from molluscs are concerned, that bacteria are in no sense detrimental?—In no sense at all. My experience in the River Wear and several other rivers in the county which are considerably polluted by sewage, is that the fish apparently not only do not suffer, but the general opinion of fishermen is that to a certain extent it is advantageous to the fish themselves.

9055. Then as to the objection on the part of the Fishery Commissioners; do they allege injury to fish to be due to the chemical impurities of the water from sewage generally, or to injury in particular from the trade refuse?—They allege it with regard to both sewage and manufacturing pollution, because in the lower

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reaches of these rivers the pollution becomes so great that it probably absorbs so much of the oxygen from the water.

9056. I was going to ask you as to that. Do you think it is so much the chemical matter in the water as the absence of the oxygen that is detrimental to the fish; the oxygen, for instance, being used up by the sewage?—I should say it is more chiefly the absence of oxygen in the polluted parts of the rivers, but an ordinary amount of sewage, say from a village discharging into an average sized river, does not by itself apparently injure fish life. It is only when the aggregation of pollutions becomes so serious as to reduce the oxygen in the water that fish life begins to suffer.

9057. Then for an effluent passing into tidal water you would be satisfied with a purely chemical standard, provided it was duly aerated?—Yes, duly aerated, and as a rule a chemically pure effluent from my experience, and I have made a considerable number of experiments, does contain a very considerable proportion of oxygen, especially an effluent that has passed through double contact beds.

9058. Do you think so whatever the process; or are you limiting your experience to double contact beds?—Double contact tanks, yes, and I should say the same thing applies to efficient land filtration.

9059. (*Chairman.*) In your experience generally I suppose you find it very difficult to define streams that are used for drinking and streams that are not; that is to say, that many streams might be used for drinking?—Yes, I suppose they might. In our county two of our biggest rivers, in their upper reaches—well, for some considerable distance down—are used for drinking purposes. The town of Bishop Auckland obtains its water supply from the River Wear, and the River Wear even within two or three miles of the intake is grossly polluted with sewage, and as you know the town of Darlington and also Stockton to some extent derives its water from the River Tees, which is a fairly pure river, although it takes the sewage effluents of Barnard Castle and Middleton, and other small villages on the river banks. The whole of the sewage entering the Tees is now fairly well purified at sewage disposal works of some kind or another, but there is no doubt all those rivers might be and are no doubt used both by cattle and human beings for drinking purposes in various parts.

9060. Would you be able to say from your own experience whether you have ever known of a case where cattle have been poisoned by pathogenic organisms going into a stream?—No, not from my own experience. I know there have been some actions in the county of Durham for deaths of cattle from drinking impure water owing to pollutions.

9061. (*Mr. Power.*) Anthrax was that?—No, I remember one case in the Chester-le-Street district where two or three cattle were alleged to have been killed by drinking from a very foully polluted stream, but I have no official knowledge of anything of the kind. The County Council never had any complaints.

9062. (*Chairman.*) But you would not be at all surprised if you heard of a case?—Not at all if the stream is very much polluted. When I say pathogenic organisms, I would not like to specify the particular organism.

9063. No, but you would not be surprised to hear of cattle suffering from drinking from a polluted stream?—Oh, no, not at all; I should think it highly probable.

9064. Just one general question of a different nature. You are the Medical Officer of Health for the whole county?—Yes.

9065. Well now, in the villages I suppose there are many where there is no system of sewage at all?—A very large number, yes.

9066. Where there are privies and something of that sort, the sewage is used for manuring and digging it into the gardens, and so on?—No, I am afraid that is not the case. In nearly all our villages, which are largely pit villages, the sewage goes into the nearest watercourse, and although we are doing our utmost to prevent this pollution, and are insisting on all existing sewage disposal works being kept in as good a condition as possible, I am sorry to say my County Council has given way to the general clamour that further action with regard to pollutions should be suspended pending the report of your Commission. It is no use, my County Council will not press the matter at present, and the result is, as far as regards the further prevention of pollution, that we are at a standstill.

9067. Then in most of the villages there is a system of drainage of some sort?—A system of drainage.

9068. There are water carriers of some kind?—Oh, yes, undoubtedly; in fact, except a few of the smallest agricultural villages I do not know a village where there is not some system of sewerage.

9069. (*Major-General Carey.*) Do you mean that the sewage is discharged into cesspools or conveyed direct into the stream?—Conveyed direct into the stream in very many instances.

9070. (*Mr. Power.*) Mainly slop sewage, I suppose?—Slop sewage; but my experience of slop sewage in colliery districts is that it is more offensive than ordinary domestic sewage. The pitmen use a great deal of soap. They wash themselves a great deal, and there is a lot of urine, and it is one of the most offensive sewages I know of, in many cases.

9071. (*Major-General Carey.*) Would the nuisance which you stated in the Tyne or the Wear be removed to a certain extent if the sewage was discharged on, say, the strongest part of the ebb tide?—I think it would very largely. I think the difficulty with regard to this chemical refuse is almost insuperable unless you carry it right out into the sea, because the volume of the liquid is so great, and it is so offensive that I do not know of any system of disposal that would possibly deal with it.

9072. (*Mr. Power.*) The rise and fall of the Wear is very great, is it not, and it has a rapid ebb?—Yes, I believe at Washington Staiths, seven or eight miles up the river, it is about 16 feet between high and low water. It flows very rapidly indeed, six or seven or eight miles an hour I believe—the tide.

9073. (*Major-General Carey.*) Have the County Council ever considered that as a requirement which might be insisted on?—The question of preventing this pollution?

9074. Discharging on the ebb?—No, they have not, because you see the greater pollution is from the county borough of Sunderland, over which the County Council has absolutely no jurisdiction.

9075. (*Mr. Power.*) Have you a standard of effluents, as a County Council?—No, no particular standard.

9076. But you yourself personally, have you a provisional one that you judge effluents by?—Yes.

9077. What do you adopt?—I think that the albuminoid ammonia should not exceed ·1.

9078. Grains per gallon?—Parts per 100,000.

9079. And the oxygen absorbed?—The oxygen absorbed should certainly, in my opinion, not exceed ·25 or ·3.

9080. (*Mr. Killick.*) The oxygen absorbed, for what time?—During four hours at 80° Fahrenheit.

9081. Should not exceed ·25?—Or ·3.

9082. Do you not think that 99 per cent. of your effluents if they contain less than one grain would not putrify?—Well, I say that is a maximum, but I have been carrying on for the last two years or more a number of experiments with regard to the double contact system of sewage disposal for a village of 4,000 or 5,000 population, and we have not had the slightest difficulty in getting the albuminoid ammonia down to even ·05 and ·06.

9083. (*Mr. Power.*) Purely domestic sewage?—Purely domestic sewage, yes, with a certain amount of coal dirt in it.

9084. (*Mr. Killick.*) But the oxygen absorbed I am asking you about?—The oxygen absorbed we get down to ·15 and ·2, usually the average is ·22 parts per 100,000.

9085. That shows the success of that particular system; but suppose a works produced one grain oxygen absorbed by your test, do you not think that might all safely pass into a non-potable stream?—No, I do not think it would; my experience of one grain of oxygen absorbed?

9086. Yes, oxygen absorbed?—Or ·15 or ·2 of albuminoid ammonia is that it usually does decompose?

9087. That it does decompose?—Yes.

9088. Have you made many experiments?—A large

number. I should think in the last two or three years I have made a couple of hundred or more analyses of sewages and of sewage effluents both from land and from the result of double contact tanks.

9089. And your opinion is that an effluent one grain oxygen absorbed four hours 8° F. would putrefy?—Undoubtedly that is my experience; I should consider that a bad effluent.

9090. What do you consider would be a chemically efficient effluent to pass into a non-potable stream?—Well, speaking generally, I consider the effluents the best that will not decompose on standing; I mean to say that an effluent which is clear and remains clear without any signs of putrefaction or change in colour, change in appearance, after standing for a few days or as long as you like, is, in my opinion, a satisfactory effluent; but effluents vary a great deal. It is rather curious that in some cases one effluent with a small amount of albuminoid ammonia and oxygen absorbed will apparently undergo changes, and become to a certain extent offensive, while another effluent containing rather more of this evidence of organic matter will not become offensive, and is a good effluent.

9091. (*Mr. Power.*) From the same bacteria beds, do you mean?—Even from the same bacteria beds sometimes, yes; but I was referring especially—I had in my mind different installations. I find myself, and it is rather a curious thing, that the effluents from land were more likely to decompose than the effluents from double contact filters, taking the amount of organic constituents in the same as equal. That has apparently been an undoubted experience of mine.

9092. (*Mr. Killick.*) These effluents that do not putrefy do you find that they contain nitrates?—Yes, nearly always. I may say the average of, I think, it is 90, at any rate it is considerably over 50, analyses of this double contact system I was telling you of, was 1 part per 100,000 of nitrogen as nitrates.

9093. Are you dealing with the whole of the streams in the county of Durham from the County Council?—Yes.

9094. And you say you do not lay down any standard, simply urge them to proceed with their works?—To proceed with their works, yes, and in several instances we have gone to the length of taking legal proceedings to enforce a satisfactory effluent.

9095. You have taken legal proceedings?—Yes.

9096. What progress are you making generally throughout the county?—Generally very good. With regard to the River Tees, as I was saying, we have got practically the whole of the pollutions stopped of which complaint was made by Dr. Barry in his Report of 1891, and taking the River Wear we have insisted on the Corporation laying down sewage disposal works for the City of Durham, and generally throughout the county we have got a large number of sewage disposal works laid down of various kinds; but, as I say, we are now hampered by the plea that matters should stand over, and they are practically standing over. If there is a case of nuisance causing injury to health, then we go on in spite of the opposition of local authorities, but where the pollution is apparently not causing danger to the health of the inhabitants on the banks or near, then we are practically leaving the matter alone.

9097. Have you any case in which you could prove that pollution causes injury to health?—Well, it would be rather difficult. I think Durham City is a case in which we should have been undoubtedly able to prove it, because there the river is kept up by a couple of dams or weirs, and the sewage used to sink down, and the river used to putrefy and became undoubtedly very offensive.

9098. But you have not proved any case in court?—No, not proved any case.

9099. What are you doing with the rural district councils?—The same thing.

9100. And the cases of isolated farms or houses?—There we have in some cases—for instance, where they have been on the banks of the Tees, which is the only river we have dealt with in this matter, we have insisted upon them putting in properly constructed cesspools, with an overflow, or in other cases we have allowed them to have tanks with radiating pipes, sub-irrigation, I may say, into gravel or sand for some considerable distance round the tank, and it gradually sinks away, and the results have been fairly satisfactory, I believe, to the county inspector.

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9101. In the case of effluents going into drinking streams, what do you ask, what standards do you aim at?—We have not insisted on any standard; as a matter of fact, we make analyses from time to time, and if we find that the effluent is bad, we at once call the attention of the local authority to the matter, and, as a rule, it receives attention.

9102. Might I ask you what standards you have in your own mind for effluents turned into drinking streams?—I say it should not exceed 0·1 albuminoid ammonia per 100,000.

9103. That is for drinking streams?—For drinking streams.

9104. I was asking you just now for non-potable streams?—I was talking of drinking streams, because we have never dealt so far with the question of discharging into tidal rivers. But I do not see myself that there should be any insuperable difficulty in getting almost as high a standard for, at any rate, the higher reaches of tidal rivers. Of course, with regard to the Borough of Sunderland, for instance, it might be sufficient, seeing it is very low down the river, if the solids were especially taken out, and it was discharged at ebb tide only.

9105. Do you think such a standard as you mentioned would be sufficient for effluents turned into drinking streams?—Well, it is a question of personal—I am not sure that it would be, but it is a question as to the possibility of generally getting a purer effluent.

9106. Would you not add a bacteriological test?—Well, you would if you could be certain as to the nature of the organisms.

9107. Yes?—I am not sure myself as to the value of that yet. I may say the whole question of bacteriology, especially with regard to the pathogenic qualities of an effluent, are at present so uncertain that it is difficult to give a definite opinion I think.

9108. (*Dr. Russell.*) This will be a chemical waste; what is known as an alkali waste?—Yes.

9109. Then, did you make any endeavour to get relief through the Alkali Act, which provides special means of getting relief from nuisance from alkali waste?—Yes. Unfortunately these works have been closed for nearly 20 years. The difficulty is, there is nobody responsible for this. The old Washington chemical works, which produced this material are defunct; have been for many years, and these huge heaps are, I believe, on land belonging to the Marquis of Londonderry, who naturally disclaims all responsibility. It is of no value to him, the land, and seeing that the expense of purifying the sewage would be so enormous the matter has been allowed to rest.

9110. Of course the age of the heap makes no difference; the owner of the land is still responsible?—Oh, so he is, but one must consider the practicability of remedying the nuisance. They undertook to lay down a new sewer, and to carry to down below the low-water mark, and that undoubtedly has very considerably mitigated any nuisance; but the pollution of the river of course still occurs.

9111. But the evolution of sulphuretted hydrogen is less?—Oh, much less.

9112. The immediate and striking nuisance is less?—Yes; the immediate and striking nuisance is less.

9113. You spoke of some bad experience you had of effluents from land treatment?—Yes.

9114. Being putrescible. Under what sort of management was this land treatment?—Oh, the farm was very badly managed.

9115. Yes?—And what is more, the land, in my opinion——

9116. Was unsuitable?—Has become not only unsuitable, but insufficient in area to properly deal with the sewage, and we are pressing the local authority now, and threatened them with an action. We have served them with notice to lay down additional works. We have recommended that they should get additional land, and also pass the sewage through a septic tank first; there is not sufficient fall by any other system.

9117. So your experience is no discredit to land treatment?—Certainly not; one can get just as good effluents by land treatment of ordinary domestic sewage as with anything else. I am not against land treatment at all.

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9118. You have no great faith in bacteriology, as applied to sewage effluents?—Not yet; I mean to say, the value of it in the future no doubt will be enormous, but seeing that it is almost at present practically impossible to ascertain the existence of any specific organism beyond the bacillus coli and the enteritidis, and that the pathogenic effects of them are not known, it is almost too soon to give a definite opinion as to the value of a bacteriological examination.

9119. Have you read the London County Council's reports on that subject?—Oh, yes; Dr. Houston's, you mean?

9120. Yes. He seemed to put it a little further on than you?—Yes, he did. He referred, undoubtedly, to the danger and possible risk of the discharge of such effluents, and I quite agree with him with regard to the discharge into any river which may be used for drinking purposes, such as the Thames, or, as I say, the Wear or the Tees, but it is quite a different matter, I think, as regards discharging into big tidal waters.

9121. (*Major-General Carey.*) In your opinion should sewage be always treated before being discharged into a tidal river or estuary?—I think so, any fresh addition; I do not suggest what additional powers might possibly be given to local authorities.

9122. I mean for the future?—Undoubtedly, for the future, I think so.

9123. Have you ever found that the growth of seaweed on the foreshore is injuriously affected by sewage pollution?—No. I was very much interested in a paper that was read with regard to the Belfast Lough sewage, and it brought back to my mind one experience I had at a small fishing village in Yorkshire where I was staying for six weeks once. There the seaweed is most offensive, and sometimes the smell from it is almost unbearable. There is a very large amount of seaweed there, growing on the rocks.

9124. (*Mr. Power.*) Is that Robin Hood's Bay?—Yes.

9125. I thought so; I too remember it.—And the whole of the sewage of the village discharges into the sea near to the seaweed, and it is quite probable, although I have had no actual experience, that the smell is due to the same cause as is found in Belfast Lough, the *alva latissimum*, I think it is; but there is no complaint of that kind on our own seaboard, in my county, in fact, there is only one town.

THIRTY-FOURTH DAY.

Tuesday, 21*st May*, 1901.

PRESENT:

The Right Hon. The EARL OF IDDESLEIGH (*Chairman*), *presiding.*

Sir MICHAEL FOSTER, K.C.B., F.R.S., M.P.
Mr. WILLIAM HENRY POWER. F.R.S.
Major-Gen. CONSTANTINE PHIPPS CAREY, R.E.
Professor WILLIAM RAMSAY, F.R.S.
Mr. THOMAS WILLIAM KILLICK.
Colonel THOMAS WALTER HARDING.
Dr. JAMES BURN RUSSELL.

Mr. F. J. WILLIS, *Secretary.*

PRESENT ALSO:

Dr. G. McGOWAN. | Dr. A. C. HOUSTON.
Professor R. BOYCE.

Mr. GEORGE VIVIAN POORE, M.D., F.R.C.P., called in; and Examined.

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9526. (*Chairman.*) You are, I think, Dr. George Vivian Poore, Professor of Medicine at University College, London?—Yes.

9527. You are Examiner in Medicine for the University of London and Physician to University College Hospital, etc.?—I am.

9528. And you have done a good deal of work and obtained a good deal of experience in connection with domestic sewage?—Yes.

9529. Well, now, may I ask you to give us a general statement of your views?—My work and experience has been mainly with domestic sewage or refuse. My object has been to show—

> That houses in isolated positions may be decent and wholesome without a public water supply or public sewers, provided a reasonable amount of care be exercised in their construction and management.

My views are set forth at length in my Essays on Rural Hygiene (2nd edit., 1894), and "The Dwelling House" (second impression, 1898), both published by Longmans.

The principles for which I contend are—

(1) That putrescible refuse should not, where it can be avoided, be mixed with water.
(2) That all putrescible refuse, whether mixed with water or otherwise, should be dealt with on the surface of the ground, *i.e.*, in the upper layers of cultivated soil. This has been the successful practice of the agriculturist in all ages and climates.

Fæcal matter should be covered with earth without delay, in order to prevent the breeding of "flies." Foul odours cease as soon as the fæces are covered with a thin layer of soil. The conversion of "fæces" into "soil" is a process which seems to depend upon the growth of fungoid organisms. This conversion appears to be quickest in "fine growing weather," when sunshine and warmth alternate with showers. It is greatly facilitated by tillage, by which the fæces and soil are commingled and the aeration of the soil is ensured. In cold weather the process is retarded, and during the drenching rains of late autumn and winter appears to be at a standstill. My experience leads me to the conviction that during the heaviest rains of winter, faeces are not washed downwards into the subsoil. After months of heavy rain the fæcal matter surrounded by a close, sticky envelope of soil remains clearly recognisable as such. With the warmth of spring following the pulverising action of frost their disappearance is rapid. The fungi for which fæces serve as a cultivating medium are many of them macroscopic and coloured, white, red, yellow, and black. The foul smell of fæces superficially buried is very transient, and I am not able to offer any evidence that the ultimate conversion of faeces into soil is accompanied by putrefactive or ammoniacal decomposition. So soon as the fæces have been converted into soil, such soil may be used again for the conversion of more fæces, and so on continuously, so that with care one can never run short of soil for the treatment of fæces.

For eighteen years my garden at Andover has received daily (except Sundays) the fæces from 19 to 23

cottages (the number has varied owing to the demolition of four cottages). These fæces are packed methodically and carefully in shallow parallel furrows less than one spit deep, and carefully covered. When this operation is complete the ground has the appearance of a carefully-prepared garden "bed." It is well, both from the economic and sanitary standpoint, to take at least two crops from land thus treated. The first crop should be of the cabbage order, and should be raised from plants, dibbled in at the earliest opportunity. The second crop may be anything suited to the soil and situation. Not only is the second crop very valuable, but the tillage entailed by it ensures the complete humification of the fæcal matter. As this process involves no "nuisance," except at the moment of emptying the buckets into the furrows, and as land thus treated increases in fertility and beauty and freshens the air by its growth of verdure, there is an obvious advantage in having such land as near the house as possible. The ideal condition is that every cottage should have a garden, and that every cottager should, every morning, decently cover in the manner I have indicated the fæcal accumulation of the previous twenty-four hours. Failing that, every village should have a sanitary garden in a central position, to which the scavengings should be brought every morning in a covered vessel. An elderly man should be appointed to act as scavenger and gardener, and in addition to his wages he should receive ten per cent. on the sale of the produce of the garden. A couple of acres of land should be ample for dealing methodically with the excreta of 1,000 persons, and such land must become very fertile, and should produce sufficient to pay wages. My garden at Andover is entered from the street, and is near the centre of the town. My cottages are mainly in two rows of nine each. In the early morning the scavenger goes to the back of these rows, empties the accumulated excreta into buckets provided with lids, and takes them to the garden (two minutes' walk), and deals with them as described. On ordinary mornings two journeys from privies to garden are required, and on Mondays sometimes four. Twenty minutes to half an hour thus suffices for the ultimate disposal of the fæces of a population which I think averages about 100. My garden has one acre, one rood, seven perches, under the spade. During the last three years the produce has been locally disposed of for £78, £82, £91. Its fertility has steadily increased from the first, and appears to be still increasing. It is a place of considerable beauty, and has been the scene of several garden parties.

Most scavenging schemes are doomed to failure by the cost of transport. The distance travelled and the weight carried are often both needlessly great.

A daily removal is to be aimed at as being most sanitary and economic. The buckets used for the transport of fæces must be scraped out and dusted with soil or ash. No washing or whitewashing is advisable, and no antiseptic chemicals must under any circumstances be used. The soil is the best of all deodorants and antiseptics.

In the middle of my garden is a well which affords evidence that no pollutions are washed downwards to the subsoil water. The well is shallow, little more than a dip hole. The bottom is 5½ feet from the surface of the ground; the sides are lined with concrete, and there is a parapet and cover. In ten years there has been no accumulation of mud, and on looking into the well one can see the stones at the bottom quite clearly. The lining of the well remains perfectly clean. The water is bright, colourless, odourless, and tasteless. The water is hard. An analysis made by the late Sir Edward Frankland is given in "Rural Hygiene" (p. 305), and it has been found singularly free from bacteria. I have no doubts as to the wholesomeness of the water, and I believe the well to be a safe one, because one can thoroughly inspect it, and see the sides and bottom, while I now that there are no sewers or cesspools, leaking under pressure, in its immediate neighbourhood. The only pollution of this well is from spiders and wood-lice, which crawl under the lid. I have not been able to prevent this, and still retain the power of looking into the well. When it is remembered that the depth of water in the well is only 3½ feet and the diameter 2¼ feet, and that the quantity of water standing in the well is not more, probably, than 90 gallons, it is obvious that a colony of wood-lice might seriously affect an analysis. In judging of the safety of such a well one must be guided by one's ordinary senses and knowledge of circumstances.

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If one can get a safe water from a surface well in the middle of a garden manured with human fæces, that is a fact of very great importance. I have drunk the water from my well repeatedly, as, also, have my friends.

In the decent, wholesome, and profitable disposal of excrement there is no difficulty. The only things needed are the will to do it, a bit of land and a set of garden tools.

But I have often been told, that it is of little use to provide for the disposal of excrement only; that slop water must be got rid of; and that as sewers are necessary it is good economy to utilise them for the conveyance of excreta as well as slop water. Even in those places where there is a public water-supply under pressure (without which it is impossible to put excreta into sewers) I doubt the justness of the above conclusions (see "The Dwelling House," p. 69). In any case the disposal of slop water must arise as an independent question in most villages.

Domestic slop water is not foul smelling until putrefaction sets in, and putrefaction should not be allowed to occur.

The waste pipes of all sinks should terminate at least 2ft. 6in. above the level of the ground; they should be short, and contain no trap.

Between the waste pipe and the ground there should be interposed (*a*) a strainer, and (*b*) a coarse filter.

The best strainer is a basket with a wisp of straw in it, which should be changed as often as it gets foul or clogged. The contents may be given to the chickens or put upon the manure heap.

The filter may consist of a special vessel or a galvanised iron bucket with a hole in the bottom, filled with coke or clinker varying in size from peas or marbles (at the bottom), to French walnuts at the top.

The effluent from the filter should run into a "filtration gutter," which consists of a perforated gutter laid upon coarse rubble of any kind (lumps of chalk, broken brick, gravel, clinker, coke), contained in a trench or arranged as a bank. Filtration guttering is now made in cast iron by Messrs. Tasker, of the Waterloo Iron Foundry, Andover, and costs 1s. 6d. per foot run. It is sufficiently stout to be taken over a path without risk of breakage from a cart or wheelbarrow. The guttering is nine inches wide, and has horizontal flanges, and is perforated with conical holes having the small ends upwards, so that the perforations cannot get jammed and clogged. The surface of the gutter can be swept clean, and while it allows water to soak away it prevents the rubble beneath from getting clogged by fallen leaves, etc. The level of the guttering must be accurately maintained by loose bricks placed at the junctions of the lengths of guttering, which are 6 feet each. The rubble is finally packed in the trench beneath the gutter.

The sides of the filtration gutter should be planted with some plant which likes moisture, such as the raspberry or black currant. The length of gutter required will depend upon the amount of slops and the nature of the soil.

Arrangements such as I have described were made for a new cottage built on the chalk near Andover in September, 1900. The straw in the basket has been changed about once a fortnight. The filter of clinkers has not been recharged at all, and there is no evidence that the slops have travelled more than six feet along the filtration gutter, of which 24 feet were provided.

After eight months continuous use (washing done at home) there is no smell of any kind, no evidence of extra moisture at the sides of the gutter, and the raspberry canes are flourishing.

Slop water when fresh not being foul smelling, there is no necessity to carry it in closed pipes. I prefer open gutters, and am convinced that closed pipes breed foul smells. This may be due to undetected stoppages, which cause stagnation and putrefaction, or possibly to the action of ferments which grow in darkness. I have no doubt as to the fact of the smells.

It is often an advantage to take waste waters in different directions, and it is obvious that by lessening the quantity of fluid taken to any one spot we lessen the risk of saturating the soil.

In country houses where water-closets are insisted on, I think it would be a good plan to treat them separately and allow the slop water to flow in open gutters.

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9530. (*Professor Ramsay.*) I fancy, Dr. Poore, that your process applies simply to rural hygiene, not to towns or cities. Your object is not to apply that system to large towns or cities, but merely to country districts?—I do not think it is practicable in towns as at present constituted. It might be in a town specially built with that idea; towns rising in colonies. That is to say, if they were properly designed *ab initio*, with closets of proper construction, so that they could be cleared every day, it night be practicable, but in cities—overcrowded cities—of an old country like this I do not think it is practicable.

9531. While we are on that subject, might I just suggest that such a town as Melbourne is very widely built; the town of Melbourne, I believe, extends over an enormous district, and most of the houses are what one would call "villa houses" in their own grounds. Do you think it would be applicable there?—I do not know Melbourne, but, from that point of view, certainly. Yes, it would be applicable, if not to the entirety of the town, to a very large part of it, certainly.

9532. Then another question is this. Such towns as Madras, Calcutta, and Bombay; they also consist of bungalows, each having its acre or acre and a half of ground; for that part of those towns you think this would be a suitable system to apply?—Speaking in absolute ignorance of the towns, yes, and taking the fact of the large appanage, I should answer yes.

9533. In your statement of evidence you make this remark, "The conversion of fæces into soil is a process which seems to depend upon the growth of fungoid organisms." Is there a proof of that?—Only naked eye proof, but wherever in turning up soil after a few weeks or a few months, after fæces have been buried, you can distinctly trace the masses of fæcal manure, and those masses of fæcal manure are riddled with fungi—riddled with fungi of many kinds. I am not a fungologist, but it is obvious you can see the mycelium, and you can see the different forms growing through the masses, sometimes red fungi, sometimes white fungi, sometimes black fungi.

9534. Do you think that the growth of fungi precedes or succeeds bacteria, or is cotemporaneous?—That I do not know.

9535. No one has ever attempted to elucidate that?—Not to my knowledge.

9536. A little further on you state that "after months of heavy rain fæcal matter surrounded by a close, sticky envelope of soil remains clearly recognisable as such." Have you many proofs of those?—Repeated proofs in my own garden at Andover. I remember some years ago, Dr. Seaton, the Medical Officer of Health for Surrey, visited my garden with another gentleman belonging to the Surrey County Council, and it was an exceptionally wet autumn. In demonstrating to them I first noticed what I state to be the fact, that in the very wet seasons, when the earth is reduced to a close, sticky condition, the fæces remain recognisable as such inside of an envelope, something like a pudding crust, and as long as this condition of things lasts the fæces do not disappear; but when the cold of winter comes, and they get broken up by the frost, and that is succeeded by the warmth of spring, the disappearance is very quick. Making repeated observations in my garden at Andover—I have made these particular observations now for 7 or 8 years—I have noticed—and I think I can state the fact without hesitation—that in wet weather in drenching rains the conversion is longest in taking place. If you get sunshine alternating with showers, a certain amount of moisture succeeded by warmth, then the conversion of fæcal manure in the soil is proportionately quick.

9537. Do you notice any difference in the character of the soil in which the fæcal manure is buried in effecting the rapidity of the conversion?—I have had no opportunity of doing so. The soil in my garden is tolerably uniform.

9538. Is it a clay soil?—No, I suppose it is, geologically, gravel. It is close to a trout stream, and is part, probably, of the old river bed; it is a very few feet above the level of the water.

9539. I think in your book, "Rural Hygiene," you state that the garden soil produced by the human fæces and mixed can be utilised again for ground closets?—Yes.

9540. And the manure can be returned profitably to the soil, and will effect the conversion of a new lot of faeces?—Yes.

9541. Do you regard that as due to nitrifying organisms developing in this mixture?—Probably; I follow there the teachings of others, but I know very well that it goes on best when air is admitted, and I suppose it is an ordinary oxidation process, due to nitrifying organisms, but I have no experiments of my own showing whether they are nitrifying organisms or otherwise.

9542. Is it necessary to empty the dry closets daily? Must the stuff put on the soil be fresh, or might the dry closets stand for a week, and at the end of a week be emptied?—They might, but to let them stand for a week, I believe, is very undesirable hygienically, and, I believe, leads to a distinct loss agriculturally. When I began my experiments in this way, some of my farming friends, practical agriculturists, of whom I know many, came to me and sent messages that if I persisted in burying fæces daily in the soil I should as they said, come to grief; that I should get no manurial value from them. But I was very desirous as a sanitarian to get rid of this stuff every day by superficial burying in the earth, and after many years of experience I have no hesitation in saying it is the best and the most economical way of doing the thing, provided you proceed as I have proceeded, that is, after the fæces have been buried, at the earliest opportunity, dibbling in cabbage plants; and what I find is that while my dung, as the agriculturists say, is "ripening," I am getting a crop of cabbages, and the ground is left in excellent condition for any other garden crop; whether it is a fruit or green peas, or any other more delicate vegetables, the ground is in beautiful condition. But it is a risky experiment to try and grow seeds in the fresh material, because sometimes apparently the seeds rot, and it is not always successful, but if you have a cabbage crop first, anything of the cabbage order, raised from plants dibbled in—I fancy that is part of the secret—then you are perfectly sure of gigantic cabbages, and you are sure of a thorough good crop of anything else afterwards that is suitable for the season.

9543. I do not know whether we can follow from your description the precise method in which you dispose of the faecal matter. You say here that you have furrows, parallel furrows, less than one spit?—One spit, that is to say, one depth of the spade; the average depth of the spade is nine inches.

9544. And carefully covered, and this takes the manure from 19 to 23 cottages?—Yes.

9545. But supposing that we take your own house as an example, do you bury faeces from one day in one little place, and then next day go on to the next, and the third day a third, or do you dig your trenches and distribute your manure over the whole area of the trench?—That all depends on circumstances. I generally select a bit of the garden that wants doing, and get my boy to proceed methodically along the trench or furrow. "Trenching" in gardening is used technically for a furrow that is more than one spit deep; the trenching is two spits at least or three, so that I use the word furrow instead of trench to indicate that it is superficial and shallow; and it must be shallow; as long as the dung is just covered for decency's sake that is the ideal condition; bury it as superficially as possible.

9546. Then do you take up this and apply it to the rest of the garden?—Oh dear no; let it remain—I never alter, I never change the position. I have my cabbage crop and then any other crop afterwards on the same spot.

9547. But when you wish to use this stuff again, do you take it after your cabbage crop has been exhausted?—As a matter of fact, I never do wish to use it again, but as a matter of experiment I have done what has been recommended—kept the stuff in a shed, and let it humify in a shed, and then have used that again.

9548. I notice that you take three crops before you re-manure the land— then is that part off which three crops have been taken re-manured in the same way?—I wish it were. but I am sorry to say that although I have only an acre and a quarter of garden and 23 cottages, my gardener complains that he does not get half enough of stuff. I am afraid I take more than three crops off the ground before I re-manure it.

9549. So that a very small piece of ground will suffice

for a very large number of people?—Oh, extraordinarily small. That is, I think, a fact that people who have not worked at this methodically do not understand. I went into the calculation the other day (see a paper in the *Lancet* for May 18th, 1901, on "Flies and the Science of Scavenging") and found from actual measurement, that a trench or furrow one spit deep, that is to say, 9 inches deep and seven inches wide and eight feet long, would be ample to take the fæces of 100 men.

9550. For how long daily?—For one day.

9551. For once?—For once, it is a mere nothing. For 1,000 men the daily area required is only 8 feet by 6 feet if it is done methodically and carefully. Of course, you may scatter the stuff all about, but it has to be buried with very great care and very great attention to detail if you want to economise your ground. Visitors to my garden (and I may say if any member or members of the Commission should so far honour me as to think it worthy of a visit they will be welcome) are surprised when I say, "There now, that spot where the earth has been turned up fresh, that is where the fæces from the cottages have been buried this morning." And they always exclaim, "Only that little bit of ground." It is very much less than one would expect, provided the work is done methodically and carefully.

9552. What do you do with the crops, the first crops, say, the cabbage crops?—Sell them all.

9553. For cattle or for human beings?—Oh, for human beings, and there is great competition for them, for the vegetables are absolutely good, first rate. In the town of Andover (my garden is in the town of Andover) it is notorious how the crops are grown, I have had scientific parties there, I have never made any secret, I have written books, and so forth, and my gardener finds a ready sale for the vegetables. He could sell ten times the quantity. This has been partly a hobby, partly an experiment of mine, and I largely recoup myself by the sale of the vegetables. This last year I sold £91 worth of vegetables and fruit out of one acre and one quarter and seven perches, and here are my garden accounts for the year, and every kind of vegetable has been tabulated. For instance, I sold £19 worth of apples, £3 worth of gooseberries, £4 11s. worth of potatoes, and £5 or £6 worth of cabbages; raspberries, rhubarb, peaches, £5 7s. 10d.; and I may say this, that my crop of outdoor peaches manured entirely in this way is, so my friends say, phenomenal. My crop of outdoor peaches never seems to fail, and I think there are gentlemen here that will admit that the money produced is exceptionally large considering the acreage, and it is exceptionally large when you consider that I am not a market gardener, and my gardener is little more than a labourer; he is an intelligent, hard working man, but he is not what would be called a skilled gardener, he does what I tell him. And so that I feel sure, as I have always said, that if this system were tried in a village or by any great landlord, that at least it would pay the wages; the return of the crops does a great deal more than pay my wages. My garden is also a place of some beauty, there are lawns to be mowed and flowers to be looked after and so forth, so that I cannot bring my accounts as a market gardener would. The £91 is not profit, I may say; it is the value of the produce. My garden is my amusement, and you cannot go into trade accounts with a thing which is half a hobby and half an amusement.

9554. I think you say there is absolutely no smell from these trenches?—Absolutely none.

9555. And, therefore, you can place them as near the house as you like?—Yes, certainly; and, of course, the saving of transport is immense. I have always adopted the view that fæces properly used are our friends not our enemies, and that they are capable of being made to return a great deal of health and pleasure.

9556. I think it would be very interesting if you could possibly give to the Commission a statement of the acreage required for, say, 1,000 people for a year on the basis of your own experience. I mean you have made one calculation as to what piece of land will take 100 people for a day; can one take that as the basis for a calculation of 1,000 people for a year?—I have very often been asked for units of that kind, and I have always been very chary about giving them, because my experience is all entirely in one soil. Perhaps, if you got to clays or sands your experience might be different from mine, and I am very chary about saying in this matter more than I know; but looking at my own garden, I should say that certainly a couple of acres of land would be enough for 1,000, because it takes me five years to go round with a population of from 100 to 120. I cannot go nearer than that, because cottage populations are always shifting, and one does not quite know from week to week how many people there are there.

9557. (*Colonel Harding.*) That is to deal with fæcal matter?—Fæcal manure.

9558. No slop water?—No slop water.

9559. (*Professor Ramsay.*) Have you any difficulty in getting people to do what you want—the population of the cottages?—Oh! I had at first. The cottages—well, they stank abominably. The old privies were a scandal, and the water-closets were worse. They were full of old boots and oyster shells, and would not act, and were in a horrid condition. When I told some of the women I was going to take away their water-closets there was an outcry; but I turned a perfectly deaf ear to the outcry, and they saw that I was firm in the matter. I said, "I shall be exceedingly sorry to lose you; I understand you have been excellent tenants, but you must make up your minds I am going to do this." And I did, and my cottages are aways full; I never have had any difficulty in getting tenants, and when my cottages get empty I am told that there are two or three people who would be glad to have them. The rents are low, and the rents have been very little raised indeed. For town rents they are exceptionally low. My highest rent, for instance, for quite a big cottage is 4s. Town rents are running up very much for small tenements, but still I remain at 4s.—my highest rent—and I have one four-roomed cottage which at one time had eleven people and a greyhound in it, and they paid me 2s. 6d. Probably, I was encouraging over-crowding there; but I was not answerable for the eleven people. I did not know what to do. I have never had any difficulty with tenants; neither have I had any difficulty in getting a scavenger—none whatever. When my scavenging post falls vacant, as it has three or four times, there are several applicants. I generally have an elderly man, I find that is best. The work is not hard, and an elderly man is very steady. And again, my gardener getting a percentage on the produce of the garden, I have no difficulty with him—none whatever. I find it very often stated by gardeners that human excrement is no use for fruit trees or anything else. Of course that is nothing but profound ignorance, as the Chinese and the Dutch bear witness, and I suppose half the garden produce we eat in this country has been imported from Holland and grown on fæces—human fæces.

9560. The cottagers, then, have nothing to do with the disposal of the sewage?—Nothing whatever.

9561. (*Major-General Carey.*) How would you apply that in a rural village? This is a system which you are suggesting as applicable to the disposal of sewage in rural villages, is it not?—Yes.

9562. Under what supervision would the disposal of fæcal manure be carried out?—Supposing the squire, for instance, appointed an old retainer—a middle-aged man—as scavenger and gardener, and allotted a piece of land in the middle of the village for the disposal of this material, and gave him a percentage on the crops, I cannot see where the difficulty is.

9563. The occupiers of the cottages could not be compelled to dispose of their fæcal manure on this piece of land?—They might be bound to dispose of it on this piece of land or dispose of it satisfactorily on their own gardens—one way or the other.

9564. There is no supervision, and there is nothing to prevent a very considerable nuisance being created if they did not dispose of their sewage in this way?—I should have thought the squire of the village might have got sufficient hold over his people to reason with them. I am strongly suspicious that, now that I have demonstrated the great utility of this material to my own tenants, a good deal of it is taken surreptitiously to the allotments. Sometimes when the allotment gardening is at its height my scavenger tells me that the material is not as bulky as it ought to be, and I suppose that that is where it goes.

9565. If you are trenching this cottage sewage.

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in your garden in a gravel soil, and you have a well within 20 or 30 feet of the trench, you do not anticipate that there will be the slightest risk to the purity of the water?—None whatever, provided it is buried superficially, and is allowed to oxidise in the superficial layers of the soil. I have in the middle of my garden a well. It is only between 5 and 6 feet feet deep, and it is lined to the very bottom with concrete pipes, and these concrete pipes are cemented at their junctions, and outside the concrete pipe is four inches of concrete, and there is a good parapet and a good cover, so that no water can possibly enter that well except through the bottom. There can be no spilling or slopping from the sides, which of course would be a danger under such circumstances, and no water can possibly enter except through the bottom of the well. That well has been made now ten years. Sir Edward Frankland reported the water as organically very pure. I have since had another analysis made of it which is equally satisfactory. And the bacteriological analyses, one of which was made by Dr. Cartwright Wood, of the laboratories on the Embankment, showed a singular purity from the bacterial point of view. So that my own belief is that, seeing that the well is kept perfectly clean, that there is no evidence of leakage through the junctions of the pipes, that I can see the gravel at the bottom to-day as plainly as I could ten years ago, and seeing further that I have drunk the water again and again and again without any hesitation, and seeing and knowing as I do that in wet weather the fæces remain in the soil and do not wash out of it, I speak with what sounds perhaps like very great boldness in this matter, and I believe you can get pure water with a properly constructed well from the middle of a garden manured in this way.

9566. I do not quite understand why the fæces are not washed through the gravel subsoil in heavy rain?—I take it the reason is that certain oxidising organisms probably do not grow inside the close pudding crust, as I call it, of soil, which forms round. I have no doubt about the fact at all. Whatever the explanation may be, I have no doubt about the fact that in strong rains the ground gets so sticky that it holds everything tight.

9567. (*Professor Ramsay.*) You would have no objection to allow us to take samples of the water?—None whatever; but I have given you reasons in this paper of mine that my only difficulty with the well is not from leakage but from insects getting into it. It has a cover which I take off in order to demonstrate it, and in consequence of this cover I cannot keep wood lice out of it, and, of course, a colony of wood lice in a small volume of water might bring bacteria or anything else. Provided the whole circumstances are taken into consideration—I have no objection whatever—I should very much court an examination. I am only a seeker after truth in the matter, and anything the Commission may choose to do I will facilitate in every way in my power.

9568. The filtration of the water, of course, would clear out the woodlice?—Yes; but would it clear out the bacteria which comes from the dead bodies of the woodlice? For instance, a very curious thing happened in the well. I took off the cover one day, and there were the woodlice, and my gardener, before I could touch him, did what a man does. He took his finger and he squashed the woodlice on the lid of the well. The lid is made of oak, covered with lead, and he killed the woodlice in that way. Well now, when you go to the well of an autumn morning and take off the lid, you will always find that there is any amount of drippings from the lid, because the water is raised by the heat of the hot day, it is condensed in the cold morning, and when you take off the lid, drip, drip, goes the water from the inside of the lid, not from the outside. The woodlice—the dead woodlice—become permeated with fungi, and you get the drippings from the fungi growing in a dead woodlouse's body falling back into the well; so that you may get very curious pollutions of that kind. And it is an interesting thing, because it shows that a well, if left to itself, may be self-polluting, so to speak, and it is a difficult problem how to keep the woodlice out. I wish I could, and yet retain the power of inspection. I attach more importance to the inspection of the well than anything else.

9569. Would a glass top not answer?—A glass top would not stop the condensation, and then I do not know what the glass top might do in letting light in; I might get a growth of algæ or something on the surface of the well if it is not used; I do not know.

9570. You have had no epidemic of any kind, I presume, in the cottages?—None whatever.

9571. Then as regards slop water. How do you propose to deal with it?—I think there is no difficulty in dealing with slop water, provided you can get the discharge pipe of your slops sufficiently high above the level of the ground to allow of the slops being strained and filtered. If you take the contents of the kitchen sink, and if you let the great bits of fat and slabs of boiled cabbage leaf, and things of that kind run direct on to a gravel filter you will soon get it choked. Since I have adopted the plan which I have described, of straining the slops, I have had no difficulty. I tried many things for straining slops—copper strainers and metal strainers, but they were none of them quite satisfactory. At last I thought to myself, "Why should not a basket and a wisp of straw do for straining the slops?" and I may say that that has answered most admirably. It seems to me to do everything that is required, and to be the best fat trap I have ever seen. The advantages are, first of all, its cheapness; secondly, that when it gets rotten, as it will in time, it can be burnt, and then the wisp of straw can be shaken out—if there are many tea leaves and so forth—over the dung heap, or you may burn it, and put in a fresh wisp of straw. In replacing the straw in that way you do a very important thing, you give a new direction to the water. Very often through strainers you find that water takes one channel, and it works one channel, and with the best intentions it refuses to be strained as it were. That is a very common thing; but if you use a wisp of straw and put in a fresh one every now and again, you are not troubled in that way. This strainer is placed upon the top of a galvanised iron vessel. I have had a special vessel made, but for a cottage I do not think it is at all necessary. A stable bucket that happens to have a hole in its bottom, and is of no use *qud* bucket, would probably be the best thing that you could use, and if the stable bucket were filled with any rubble such as broken clinker, varying in size from a pea at the bottom to a French walnut at the top, you would then get your slops well strained of almost everything and the most you will get in the effluent is a cloudiness from soap without any solid particles left in it. And then I let the slops run finally on to a "filtration gutter" which works most admirably on the chalk soils of Hampshire. I have brought a sample of a filtration gutter. At first I built these filtration gutters with malting tiles. I found that was expensive, and difficult, so last summer I went to a local firm of iron-founders, Tasker and Son, and I got them to make me a filtration gutter of cast iron. This filtration gutter is strong enough when laid to allow a cart to pass over it, so that it can be taken across the path round a house. This is a very great convenience. The holes in the filtration gutter are conical; they are smaller on the top side they they are on the under side, so that they are not liable to get jammed, and, as far as my experience goes, they never do get jammed. The surface of the filtration gutter can be swept clean. One of the difficulties with gravel filters is that leaves blow on to the surface and your filter very soon gets clogged; but this gutter can be swept perfectly clean, and your filtering goes on. It is an exceedingly simple thing; but, as far as my experience goes, it answers most admirably, and for getting rid of the slops of a cottage decently I do not think it leaves anything to be desired. I have here a photograph of a cottage which was built last year, and the filtration gutter has been in use since last September. The filtration gutter was laid in this way. First we dug a trench 18in. wide and 18in. deep and 24ft. long, and then from the filter we laid our filtration gutter, maintaining the level by columns of brick, and giving the slightest possible slope from the cottage. Having got the level we filled in the trench with rubble, and planted the edge with black currants and raspberries. There is first the basket, then the filter, and finally the filtration gutter. My cottagers do their washing at home, so that we are dealing with complete cottage slops. The wisp of straw has been changed once a fortnight about. The filter has never been changed, and I have no evidence whatever that the liquids have ever reached beyond the first 6ft. of the gutter. I provided 24ft. (in four 6ft. lengths) wishing to be safe; but I have no evidence whatever that the liquids have ever reached more than the first 6ft., and that entirely accords with my experience elsewhere. I bring this forward as the latest and

the cheapest idea that I have got. I may say that this is not patent; there is no patent of any kind; I bring it forward as a notion that has been at all events with me satisfactory.

9572. (*Major-General Carey.*) Did your basket continue to act as a filter without clogging up?—Oh, yes. The length of time largely depends upon the thriftiness of the housewife, and the amount of cooking that is done. I have particularly asked that, between my visits, the thing should not be touched unless it was absolutely necessary, and I think if you watch a sensible, thrifty, family of that kind—there have been three people in this cottage—it is perfectly surprising how little is wasted. They have no chance, of course, of turning taps and letting any amount of water run to waste. That is impossible, the water for the cottage has all to be pumped, so that there is no dripping, no waste, and I am inclined to think that the estimate of 10 gallons of slops per head per diem is very much in excess of the truth.

9573. (*Professor Ramsay.*) This is on chalk soil, of course?—Chalk soil.

9574. Would it not be more difficult on clay soil?—Yes, undoubtedly, and on clay soil you would have to put the filtration gutter on an artificial bank of gravel. Of course, everything is difficult with clay, which requires filtration whether it is a bacteria bed or anything else. To get rid of your water on clay is always a problem.

9575. One point I do not quite see; I do not know whether it is quite clear to other members of the Commission. Why do you expect the water to run more than 5ft.—owing to the holes in the first section being clogged?—Yes. If the gutter got clogged and failed.—(*The witness here produced two small bottles of fluid and continued.*)—General Carey was asking me about the well-water; perhaps these may interest him, as showing the purifying effects of filtration. The parent of this fluid is pure urine. It was filtered through sawdust in the year 1895, so that that urine is six years old, and there is no suggestion of urine about it at all, neither has it ever putrefied. Then this again is urine of 1897, that has been slowly filtered through clay, and there is no suggestion of urine, and it has never putrefied.

9576-7. (*Mr. Killick.*) Professor Ramsay was asking you about India and Australia; do you know anything about China—the system of sewage disposal?—No, only by reading; I have never been there.

9578. There it is returned daily to the earth?—No, I think not, and if I may say so, I think that is not the Chinese method. The Chinese, as far as I am able to understand, have a different climate to ours. It is a much more calculable climate with regard to rainfall. I may be wrong, but this is the conclusion I have drawn. It is much hotter, and the Chinaman finds that the best way of forcing his crops is to mix the fæces with a certain amount of urine and water, and he keeps them in tubs and buckets, and he does not use them until a certain green scum appears upon the surface of the water, and when the green scum appears the Chinaman seems to know that that is the precise moment when the mixture will do his plants good, and he doses the individual plants with the mixture. I do not think the Chinaman does what I have done at all. He collects the stuff in towns, and keeps it in tubs, and applies it liquid, or semi-liquid.

9579. It is removed daily from the house?—I believe it is.

9580. Then your opinion is that the safety of your system consists in the fæces being kept dry?—Yes, you stop the putrefactive changes which are, at all events, a great annoyance to the nose.

9581. Then, if the fæces are kept dry it is not desirable that they should be transported any distance?—No, I think there are many advantages in using a piece of ground for fæcal farming or burial that is handy, because you do away with the expense of long transport, and you do away with the little danger there may be of spilling about the streets, and so forth. Then again by daily removal you do away with the great weights. For example—may I just quote an example? The pails used in the great municipalities very often weigh 50lbs. when they are empty, and when they are filled with water—I filled one with water one day and weighed it—they weigh 186lbs.; and one of these great pails is as much when it is full as two men can stagger under to get it on to a lorry; and, of course, if the covers do not fit there may be a spilling, and it is very disagreeable work. Now, my scavenger going every day—my cottages are mainly in two rows, and at the back of each row of nine houses he has all the privies close at hand—he takes two buckets; and empties the other seven into them; he puts a cover on, and bearing one bucket in one hand and one in the other, he transports it to the garden, which is a very few hundred yards distant, so that the transport is a very small thing. If you have a daily transport, and if you have buckets of which one man can carry two, instead of a receptacle which requires two men to carry, then I think it can almost be demonstrated that you can do four clearances for the expense of one, so far as wages go.

9583. (*Professor Ramsey.*) Do the cottagers put earth system you advocate—is not suitable for populous places?—No, unless you can get daily removal; but I do not believe myself that there is any difficulty in the matter, provided the place is properly built for it. It must be properly built. If inconvenient—if one has to go into the house and upstairs—anything of that kind—then I think it is quite impossible.

9583. (*Professor Ramsay.*) Do the cottagers put earth in the pails themselves?—No, I find they have any amount of ash they might put in; they never do anything of the kind, and it is no good expecting them to do it; but as the stuff goes immediately to the earth, and is not allowed to lie about, I think that is a matter of very small moment.

9584. But do the pails, then, not get very dirty?—They are not more dirty after using them six weeks than they are after using them six minutes. Very often they are much more offensive in the first six minutes than they are at the end of six weeks.

9585. (*Colonel Harding.*) Your idea for purification of sewage is the absence of drains?—Certainly.

9586. I have myself found in my experience of one village, where I have given the matter some attention, that the drains they have, have been a source of very grave danger?—Yes.

9587. Owing probably to the fact that foul emanations and productions arise in them because they are closed?—I think so.

9588. And you think, therefore, that light and air are a protection?—Yes.

9589. And therefore that the old-fashioned way of allowing the slop waters to run down the streets, as is the case in many foreign towns, is possibly a safer course than carrying them in closed drains?—Well, it has its advantages and its disadvantages. There are many disadvantages in leaving drains open. Things get thrown into them, and so forth, in a large population; but otherwise from the natural point of view, apart from artificial meddling, I think it is distinctly better.

9590. And looking upon the fungoid and bacterial growths as beneficent, you would think the use of antiseptics in connection with household pails and buckets is a mistake?—If you use antiseptics of any kind, you to a certainty get agricultural failure, and I believe the disrepute into which human fæces have fallen in this country is because chemicals of various kinds have been added to them. It is perfectly astonishing how small a quantity of carbolic acid, for instance, will kill strawberry plants. All tar-products are the same. If you make a tar path in your garden, as I have done, you will find that things will die close to the edge of that for long distances, and I take it that it is due to the tar products permeating the soil in some way and killing the plants. In a country place that I know, the local surveyor protested he could grow nothing; but when I saw his arrangements I could smell nothing but carbolic acid, and of course that is fatal to making any use of fæcal refuse. I should trust to the earth and the earth only.

9591. Then how far is the excellence of the soil in your own garden at Andover responsible for the results which you have obtained. Would these results be likely to be obtained, do you think, in other places where the soil is much heavier—more clay?—I think so; I see no reason why it should not. And with regard to my own garden the productiveness of it has increased, and is steadily increasing. That I have no hesitation in saying.

9592. I may say that when I induced a friend to adopt earth closets, largely from having read your excellent

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book on "Rural Hygiene," he found a difficulty. His gardener objected absolutely to deal with it, but the probability is that a large pail was allowed after a week's use to become full, and then would be rather disagreeable to handle?—Yes, that might be it. It might be that a dealer in nitrate of soda was giving him a commission.

9593. I do not think that?—I have a very strong suspicion of some of these things.

9594. Anyway, your suggestion is that in order for this work to be accomplished easily, in order that this material may be handled readily, it must be done daily?—Certainly.

9595. That is essential?—I think it is essential to success.

9596. A large pail must not be allowed to accumulate this matter for a week or ten days?—If it is carefully covered with earth, of course there is no offence from it, but very often it is not carefully covered. I think daily removal is the essence of the whole thing, and then you do not get the heavy business of dealing with a large quantity at once.

9597. Then have you formed any opinion as to the advantage of a cesspool in connection with a household to let the slop water, the bath water, and the water-closet, if they will have one, go into cesspool, and then deal with the effluent from such cesspool at one of your filtration channels, would that be practicable?—No. But why put off the evil day, why not deal with the slop water before it putrefies? Why not deal with it while it is perfectly sweet? My slop water is absolutely sweet, and if I let it run into a cesspool it would stink in a few days, and the dealing with it would be more difficult and more objectionable.

9598. You think the cesspool effluent could not possibly pass through a channel as you have been suggesting to us?—The whole object is to try and avoid the necessity of a cesspool, which I look upon as an evil.

9599. You have been telling us that in cases of which you have experience locally, the volume of water to be dealt with is very small, that 10 gallons a head is probably an exaggeration?—In a cottage.

9600. In a cottage, but in country houses and many rural districts where a much larger water supply is available, that volume would rise to 30 or more gallons a head, would it not?—Certainly.

9601. Would you practically deal with it through such filtration channels?—There is a great deal of water in every country house, which, when it is discharged, is practically clean. In the present day a man has a bath in 30 gallons of water; the people indulge in various athletic games and afterwards they have a bath; but you may drink that water; there is nothing offensive in it to the eye or the nose to warn you that it may not be drunk. Why on earth that should ever be allowed to run into a cesspool I cannot conceive. It seems to me to be creating difficulties, and when you run it with fæces, in order that the fæces may putrefy, and that the whole thing may become a nuisance, then I cannot understand it at all.

9602. Well, your suggestions, Dr. Poore, certainly are very interesting, and I quite agree that if they are carried out with intelligence they probably would be extremely successful but the practical question arises. You have been preaching in a most able, not to say amusing way for some years, and has any extension of your system been carried out in your own district for instance?—In the town itself? No.

9603-4. But what is the population?—6,500 odd.

9605. Has your excellent example—I am a thorough believer in its success in your own case, and I am quite sure if it is intelligently carried out that it will act excellently—but has it been followed locally, has it been possible to extend it locally in Andover and the neighbourhood?—I can refer you to Bemerton near Salisbury, where Canon Warre, the rector of Bemerton has built cottages, and has dealt with them exactly as I advocate, and with perfect success.

9606-7. Can you give us an instance of a village dealt with on that plan?—No, I cannot. I find that the law is against one; I find that the law states—I think I am right in saying this—that where two or three cottages happen to drain into one pipe, that that pipe becomes a sewer maintainable by the Council of the district. I find that that fact alone is too much for me. I have been consulted by many villages—I think I had better not name them—notably one in Surrey, for instance, where the houses were scattered all over the place. Simple people are easily persuaded that a sewage scheme is a good thing for them, it will lead to the expenditure of several thousand pounds, and that then the contractors and the men will want to be fed, and so on; then of course a sewage scheme is undeniably a magnificent thing for a man who happens to own eligible building sites along the line of sewer, and if you have the law as it is, so that the municipality is bound to take the effluent and deal with it. and if you poll the municipality the voting is almost sure I think to be in favour of sewerage.

9608. Then does it come to this, that you suggest this to us as applicable rather to individual outlying houses or to small groups of houses independent of any local authority, however small?—Yes, what I have always advocated, and what I might say again is this, that I think it is a pity that the sanitary well-doer cannot be, so to say, encouraged. Take my own line of action at Andover; I have done this largely from scientific interest, but I know some people there regard me as a little bit of a fool, because I have to pay my rates, and they cannot conceive why I should bother about my sanitation. If some regard could possibly be shown to the man who tries to do his sanitation and not create a nuisance, I think that we should improve in those matters.

9609. (*Dr. Russell.*) How does your system work in winter time, in hard frost, say?—I have never had any difficulty at all—it is rather a curious thing, I am glad Dr. Russell has asked me that question—excepting once. I should like to tell you how I think it was. On one winter, I was running all my slops across the garden with a very clumsy arrangement, and we had a very hard winter, and the neighbouring river was frozen tight, but my slops continued to run away. Two years later I was doing just the same thing, but I was intercepting all the urine for a special series of experiments. None of the urine was going down with the slops. Then my gutter froze. Whether the urine, by virtue of its salts or something else, kept the thing fluid I do not know, but there has never been a difficulty at all.

9610. The trenching operation succeeds?—Well, in the depth of winter, of course, then you are bound in very heavy frost to store the thing and keep it with ashes and so forth, until the weather mitigates, that goes without saying.

9611. That is it?—As you know, sir, in the depth of winter, these things are never a nuisance. It is the summer and autumn that is the dangerous time.

9612. That means that in winter time you have to institute a temporary ash-heap or midden?—Yes, in winter.

Dr. EDWARD EMANUEL KLEIN, M.D., F.R.S., called in; and Examined.

Dr. E. E. Klein, M.D., F.R.S.

9613. (*Chairman.*) You have, I think, studied the bacteria contained in sewage? Would you mind telling us generally any results you have obtained?——

1. The typhoid bacillus has been demonstrated in sewage:

(*a*) By Dr. Andrews and Mr. Lawes in sewage of the Homerton Fever Hospital.

(*b*) By myself. The typhoid bacillus was isolated from fluid during the epidemic of typhoid fever in Worthing. This fluid had escaped from an old faulty sewer, and had gained access to the well supplying the water of the town.

2. Bacillus coli—a bacillus abundant in sewage—is not always the harmless microbe that some consider it to be. Some strains of b. coli are distinctly virulent, *e.g.*, the b. coli derived from diseased intestine is conspicuously more virulent than that of the normal intestine. A number of diseased conditions of the human subject have been proved to be caused by b. coli, *e.g.*, certain forms of pneumonia, abscess, cystitis, some cases of English cholera.

3. The spores of bacillus enteritidis have in several instances caused epidemic diarrhœa.

There exists at present a great deal of misconception

with regard to what are deemed to be variations in the virulence of this microbe, chiefly on account of the confusion of this microbe with other two (non-pathogenic) bacteria, named bacillus butyricus and bacillus cadaveris sporogenes. All three microbes are generally associated in sewage and other matters presumably derived from sewage pollution or manure.

4. Bacillus pseudotuberculosis occurs in sewage and sewage effluents, and I would particularly draw attention to the virulence of this microbe when administered by way of the alimentary canal.

5. Another specific microbe, which I have isolated from sewage, is the bacillus pyogenes cloacinus. However, this microbe is not of frequent occurrence.

6. A microbe which may, on occasion, be present in sewage is the cholera vibrio; such was the case in 1893 in a Hull drain; a boy who with others bathed in this drain died of Asiatic cholera, the others escaped with severe diarrhœa.

7. A subject to which I would call attention is the risk of edible shellfish—oysters, mussels and cockles—carrying typhoid, and perhaps cholera, infection to the human subject.

8. Pathogenic microbes do not indefinitely retain their vitality in sewage. As a matter of fact, many do so only for a relatively limited time; the longer, therefore, they are retained in the sewage the less likely are they to survive. A like limited vitality of pathogenic microbes occurs also in soil. It is therefore desirable in order to eliminate as much as possible harmful pathogenic microbes from sewage, to delay as much as possible the passage of sewage effluent into rivers. This is best achieved, and achieved with a double purpose, by slow soakage of the sewage or its effluent through land.

9614. Do I understand your opinion to be that in order to eliminate as much as possible harmful pathogenic microbes from sewage it is desirable to delay as much as possible the passage of sewage effluent into rivers?—Yes.

9615. Well, that might be described in other words, might it not, that the more filtration you have the more you will eliminate those microbes?—That is so, that would apply to particulate matter. The oftener and the more you filter, perhaps I should add the better you filter, the more you would eliminate the particulate matter.

9616. Quite so. It is more a question of quantity than of quality that you would attach importance to?—Quantity?

9617. Well, that is to say, it is the amount of filtration as distinguished from the material that is used in filtration to which you would attach most importance?—I do not know that I mean it in quite that sense; because suppose you were dealing with very minute bacteria, and the filter would permit these to pass through, it would not much matter whether you passed them twice or three times through that filter.

9618. Oh, quite so; they would not be filtered at all if they went through the filter?—No.

9619. So long as you could get an effective filter, it would not, I gather, be in your opinion important of what materials the filter was made?—Not at all.

9620-21. Then there is a question that I wanted to ask you, and that is about anthrax; have you had any experience of cattle attacked by anthrax?—In what sense? I have seen anthrax in cattle; I have examined such cattle.

9622. You have seen cattle suffering from anthrax?—Oh, yes.

9623. And have you any knowledge of how the disease might have been caught by them?—In the cases I refer to, which included cattle and sheep, there was no question as to how they contracted the disease; that did not come under my knowledge. But I know that the washings from a Bradford wool sorter's establishment which went into a stream have produced anthrax in cattle that drank of that water.

9624. Then you mean that cattle caught the disease from drinking infected water?—Yes.

9625. Do you know that as a matter of fact?—Yes, I know that as a matter of fact.

9626. (*Mr. Power.*) Anthrax was detected in the effluent of which the cattle drank?—Oh, yes, certainly.

9627. In the last paragraph of your evidence you say, "pathogenic microbes do not indefinitely retain their vitality in sewage." You were insisting just now on the usefulness of filtration in the arrest of particulate matter; but were you not thinking that all those microbes which did go through might, owing to their detention during the filtration process, have to some extent lost their pathogenicity?—Certainly it may have become altered.

9628. They may have become altered as to their virulence; were they altered morphologically also?—Yes.

9629. You have facts that show that, have you?—Yes, I have facts which show that certain pathogenic organisms kept under conditions such as differ widely from those obtaining within the animal body, are liable to be altered both in their morphological character, and also in their pathogenicity. I do not say all become thus modified, but certain of them do; for instance, the cholera vibrio does readily.

9630. Are you speaking now of pathogenic microbes passing through land or through artificial filters?—No, I am referring generally to conditions which one might describe as non-natural conditions for pathogenic organisms. Their natural condition is the animal body. Everything outside the animal body is not a natural condition for these micro-organisms.

9631. Have you made any observations as to the conditions under which pathogenic micro-organisms in sewage or in water actually multiply, become more numerous?—For a certain time, yes, they do; it depends on circumstances. For instance, nitrate added to sterilised sewage would be a very good means of enabling certain organisms like the typhoid bacillus to multiply, and this multiplication might go on for some time.

9632. Do the typhoid bacilli in those circumstances multiply at the expense of the nitrate; have you had any chemical examination of the "nitrate sewage" before and after multiplication in it of the typhoid bacilli?—No, I have not had any chemical examination.

9633. The multiplication of the typhoid bacillus that does take place either in sewage or water is not very long sustained, is it?—No, it is of only very short duration; there soon appears a decrease in the number of the bacilli.

9634. Would it be a matter of days or weeks during which the increase takes place; it is not invariable, is it, that increase takes place under laboratory conditions?—I have not the blue book with me in which my experiments are described; I can only speak of general results. (*Blue-book handed to witness.*) Here is a series of experiments described wherein typhoid bacilli were put into sewage to which nitrate had been added, and I find here that there was an increase in nine days; then there was 15 days afterwards a decrease—a distinct decrease. On the 24th day there was a still further decrease. So one might say that for a comparatively short period there was an increase, and then a decrease set in till practically they disappeared.

9635. That is the typhoid bacilli disappeared?—Yes.

9636. You have made parallel experiments with cholera vibrios, have you not?—The experiments with cholera vibrios did not turn out quite the same. There was one instance in which the cholera vibrio seemed to prefer the pure sewage to the nitrate sewage; but in another experiment the reverse was the case. But in both experiments the vibrio tended to die out in the sewage.

9637. Did the cholera vibrio undergo morphological change?—Not in this instance. The morphological change to which you refer occurred when this vibrio was placed in sea water.

9638. I was intending to ask you about that later. You have in that same volume a report of some experiments of adding these two microbes, the typhoid bacillus and the cholera vibrio, to fresh water?—Yes, to fresh water.

9639. To fresh water of various sorts, tap water, distilled water, and rain water?—Certainly, yes; and there was a decrease, but they survived much longer than had been generally stated to be the case. The reason I think why the results which I obtained differed from those that had been obtained by others is very easily understood. As a rule when experiments were made with reference to the vitality of organisms in water, the experimenter was satisfied if, in a small

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quantity of water examined at the beginning of the experiment he found many, and if in a similar small quantity of water of the same sample at a later stage, he found few, and then still later found none. If this happened he came to the conclusion that this organism dies in the water.

9640. Are you speaking of cubic centimetre as the amount tested in each instance, or of a less quantity?—Of a cubic centimetre. Well, I point out that this conclusion is not justified, because, supposing you put into 100 cubic centimetres of water 100 typhoid bacilli, and by shaking the sample you uniformly distribute the bacilli throughout the water, then each cubic centimetre would contain one typhoid bacillus. But supposing these 100 typhoid bacilli, as they generally do, decreased in number; that they did not find sufficient nutriment in the water, and that the weaker ones went to the wall; so that after three days there were left 50 typhoid bacilli in the 100 cubic centimetres. If you then repeated your experiment with one cubic centimetre, and failed to find any typhoid bacilli you might conclude that the typhoid bacilli had all died, whereas there were still 50 remaining. The method of experimentation that I recommend is this; namely, to take larger and larger quantities for examination.

9641. As time went on, to take larger quantities of the originally infected water for testing purposes?—As time went on. When you come to the point, for instance, that not even 5 cubic centimetres of the water yield any colonies, then use the whole of the remaining water. Supposing there are left 80 cubic centimetres in the flask, you add to these 80 cubic centimetres of water a small quantity of phenol broth, so as to make of the whole a suitable nutritive medium, and then you incubate it. If one single typhoid bacillus be living it would multiply, and next day—in 24 hours—you would find the fluid would be swarming with the bacilli. If you find them at all after 20 days, 20 days obviously was not sufficient to kill off all the typhoid bacilli; although they had decreased in numbers considerably they had not died because at least one was still left.

9642. Before, therefore, you can say that a given sample is actually free from typhoid bacilli, you have to take, if the sample be large in amount, many cubic centimetres and obtain the particulate matter of this large quantity by passing it through a (say) Berkefeld filter?—Yes, when you fail, say in 10 cubic centimetres to discover any bacilli you must take the whole of the rest and deal with it in some such way. It is for the reason that this has not been done that the statements that have been made as regards the very short vitality of microbes in water must be taken only to mean that they have decreased therein.

9643. In a particular experiment with typhoid bacillus in water while you were noting the decrease in numbers, did you make any parallel observation as to their morphological aspects?—In some experiments I did. The typhoid bacillus retained all its morphological and cultural characteristics.

9644. At the end of how many weeks was that?—About six. They were unchanged in the above respects, I mean to say as long as the experiment was positive; in some experiments this was the case after several weeks.

9645. And the physiological effect of the bacillus, was that decided at the end of the period?—It is very difficult to decide the physiological effect of the typhoid bacillus, because it can only be tested, and that relatively, by subcutaneous injection. If you inject a fraction of a culture of the typhoid bacillus into the peritoneal cavity of a guinea pig, the guinea pig would generally die; one-fifth, one-sixth, one-tenth, or one fifteenth of a culture may be fatal according to the different derivation of the typhoid bacillus. I mean the typhoid bacillus in its particular effect upon the animal differs when derived from different sources. For instance, it is perfectly well known that typhoid bacillus directly taken from the spleen at the post-mortem examination of a typhoid patient would produce a fatal effect on the guinea pig with one-twentieth of a culture, whereas in another case perhaps it would require one-fifth of a different culture to produce the same effect. I think perhaps you are referring to another series of experiments that I made with the cholera vibrio from sea water.

9646. No, I was coming to that later on. I think you made experiments, did you not, with colon bacilli in the same series with the typhoid bacillus?—Yes. In one set of experiments I found that bacillus coli appeared very little, if at all, hardier than the typhoid bacillus, when submitted to the several different waters—as for instance, sterile tap water and non-sterile tap water—and that its persistence in the water for so long as a fortnight was doubtful. But in a second set of experiments, and working with bacillus coli from a different source, these micro-organisms were easily recoverable from tap water, sterile and non-sterile, after the lapse of fully two weeks.

9647. Would you now tell the Commission broadly the results of your experiments with the cholera vibrio?—The experiments with the water?

9648. Yes, adding them to water?—There are some experiments with reference to West Middlesex water, New River water, and Kent water, infected with the cholera vibrios, and they had considerably diminished in a few, and were quite superseded by others in eight days, using small quantities for experiment. But testing, after 36 days, large quantities of the infected water, we still found some living cholera bacilli. From these experiments it follows that the cholera bacillus survived for more than five weeks in these water samples; they had decreased, of course, enormously, but still there were some left.

9649. (*Dr. Russell.*) Was that ordinary water?—Yes; West Middlesex, New River water, Kent water.

9650. (*Mr. Power.*) In the fresh water did you find any morphological modification of the cholera vibrio during its retention in the water?—I made no definite observation of the vibrio in that sense in fresh water.

9650*. Would you now tell the Commission as to the behaviour of the typhoid bacillus and the cholera vibrio in sea water; you have made a number of experiments?—Yes, I have made a number of experiments in reference to that matter. Whereas the typhoid bacillus did not show any alteration in its cultural characters, the cholera vibrio showed very distinct alterations, which alterations manifested themselves first of all by modification of the power of liquefaction of gelatine, because the typical cholera vibrio liquefies gelatine fairly rapidly. The cholera vibrio that I experimented with was derived from a case of a sailor who came from St. Petersburg. There was cholera then at St. Petersburg, and this sailor died—was isolated here at Denton Hospital and died there—and from his intestine the cholera vibrio was derived with which these experiments were made. Well, comparing the stock culture with cultures obtained from the sea water infected from the same stock culture, it was noticed that in five or six days the cholera vibrio from the sea water refused to liquefy, or did not liquefy gelatine at the same rate as the vibrio derived from the stock. Further, it altered its character with reference to growing at blood temperature. Some of the cholera vibrios from sea water refused to grow at 37° C. Cultures of these were obtained, but the vibrio did not produce the cholera-red reaction with sulphuric acid, or produced it only very feebly, and later on did not produce it at all. However, this did not depend, apparently, wholly on the duration of the vibrio's sojourn in sea water; partly it had relation to the source whence the vibrio was originally derived. I remember very distinctly there was one vibrio which I still keep up in culture, which on the Continent they call "Vibrio, Klein, No. 3." It is mentioned in the blue-book as "No. 3." That is a vibrio which from the outset, when it was first obtained from the sea-water tank, liquefied gelatine most rapidly; in 48 hours it gave cholera-red reaction very slightly, and was highly pathogenic—more pathogenic than its parent, the St. Petersburg vibrio. I mean a smaller dose was required to be injected into the peritoneal cavity to produce a fatal result in 24 hours. Well, this vibrio morphologically appeared the same as its parent, except that it liquefied gelatine very rapidly and gave cholera-red reaction very much feebler. Then another difference was noticed among these different species or varieties of vibrio that were obtained from such cholera-infected sea water, viz., a difference with reference to their behaviour as regards "serum reaction." First as to reaction *in vitro* of the true cholera vibrio with the blood of an animal protected by repeated injections with small doses of the cholera vibrio. In an animal protected by this vibrio the blood acquires the power to agglutinate an emulsion of the cholera vibrio; adding a drop of blood of such a protected animal to an emulsion of the cholera vibrio, there is produced a precipitation, while the fluid becomes clear. Well these different varieties that I mentioned to you just now behave very differently in this

respect. When the blood of such a protected guinea-pig was tested upon their emulsion, it was found that some of the above varieties gave the reaction feebly, others gave the reaction not at all. The particular variety mentioned as No. 3 does not give the reaction *in vitro*. Then there is another reaction, viz., the reaction *in corpore*, or Pfeiffer's test: the blood of a guinea pig protected against cholera by repeated inoculations, has the power to destroy a fatal dose, or to neutralise a fatal dose, of cholera vibrio injected along with it into another animal.

965. Injected subcutaneously?—Intraperitoneally; for instance, if a drop of blood, or a certain proportion of blood, of such a protected guinea-pig is added to an otherwise fatal dose of cholera vibrio and injected intraperitoneally into a normal guinea-pig it has no effect on that guinea-pig. This is the test *in corpore*, or Pfeiffer's test. While some of these varieties of vibrios obtained from the sea water retained the original character—viz., that of being neutralised in their potency by the blood of a protected guinea-pig—others had lost it. So, there is no doubt that there was evidence that the sojourn of cholera vibrios in sea-water is capable of altering the cultural character and also the physiological character of this vibrio.

9652. Did you observe any multiplication of them at any time in sea water?—At first there was.

9653. A little?—A little.

9654. And the changes you have noted were effected in 36 days, did you say?—No, much shorter than that.

9655. Much shorter?—After five or six days.

9656. In particular instances, quicker in some samples than in others?—Yes.

9657. Have you made any observations differentiating the morphological characters—and so far as you can judge of them—and the physiological properties of typhoid bacillus and of cholera vibrio in sewage before going on to land and in the effluent after passage through land?—Well with reference to typhoid bacillus I should not like to express an opinion because I have not made any direct experiments upon it, but I should think a delay of the sewage in passing through land would probably—perhaps I had better say might—alter the typhoid bacillus contained in the sewage.

9658. A delay of what time are you thinking of, hours or days?—Days.

9659. And as regards the cholera vibrio?—I would put the time shorter.

9660. Modification, morphologically and physiologically, of the vibrio would take place in shorter time?—There was one instance where the sojourn of cholera vibrio in sewage distinctly showed that it altered its character—that was the case of the Sutton Dyke, at Hull. The vibrio in the Sutton Dyke, of Hull, the water of which is probably mainly sewage, was altered. It was altered at any rate in this that it liquefied gelatine much more rapidly, and it gave the cholera reaction much feebler than Koch's vibrio.

9661. When recovered from the water?—From the water, yes.

9662. It behaved very differently from that vibrio which you obtained from the Hull boy at the same date—the boy who died from cholera?—Certainly.

9663. (*Professor Ramsay.*) Have you any experience of septic tanks, Dr. Klein, in this respect?—I have examined the effluents of septic tanks.

9664. Have you found any disease bacteria in them?—Well, I have found a good many bacillus coli, and have found a good many spores of the bacillus enteritidis.

9665. Yes, these are understood to be common in sewage effluents?—You asked me if I found any organisms that were pathogenic.

9666. Any others?—No, I have not found any others.

9667. You distinguish between coli which are pathogenic and those which are not pathogenic?—Certainly.

9668. And you found pathogenic coli?—Yes; but when the question is put to me that pathogenic bacillus coli is common, as I understood you to suggest, I certainly demur to that.

9669. Is it not a very common bacterium?—Certainly.

9670. But there are varieties of bacillus coli, some of which are pathogenic and some of which are not?—Some of which are pathogenic and some of which are not.

9671. (*Mr. Power.*) Have you got the pathogenic form of B. coli out of your effluents?—I did not test the physiological action of B. coli from any effluent.

9672. (*Professor Ramsay.*) Have you any experience of nitrifying organisms?—No.

9673. Or of the organisms which produce sulphuretted hydrogen?—No.

9674. Has it occurred to you at all as to how effluents could be sterilised, so as to kill bacteria?—I should think by heat. About two or three years ago there were submitted to me some papers asking my opinion about an apparatus, the object of which was to sterilise effluents. The answer that I gave was that if this apparatus—which was not then constructed, it was only on paper—was possible of construction, I should be willing to go into the matter. And that was done. An eminent engineer and mathematician examined that scheme and the drawings, and his report was that this apparatus was perfectly possible of construction; that, in fact, it would be an easy matter. This apparatus had for its object to separate the solid matter of sewage from the fluid, and to sterilise the fluid; and, from what I understood from that description, the amount of ammonia that you would obtain by the process would pay almost for the coal—for the fuel—for keeping the apparatus going. That is, of course, a question, you will understand, I cannot say anything about; but, as regards the sterilisation, that, of course, was possible.

9675. Could you put the Commission on the track of the people you speak of?—I could find it out; I think I have got notes of the matter.

9676. Thank you very much?—I think Professor Unwin had to give a report on the apparatus itself.

9677. I know him very well; I could easily get it from him in that case?—Oh, I could find out.

9678. (*Colonel Harding.*) I should like to ask, Dr. Klein, whether the danger arising from the presence of pathogenic bacteria in sewage is mainly connected with the drinking of water into which such sewage, or such sewage effluents go?—Well, perhaps, not quite; not alone drinking, because water might be used for various other things. Now, for instance, a large number of abscesses are known to be due to bacillus coli—also cystitis is known to be due to bacillus coli.

9679. That is the external use of water might also bring about dangerous conditions?—Yes, certainly.

9680. Now, do you think that it really is a point that we, as a Commission, ought to insist on, that in view of the danger arising from these pathogenic germs, the effluents should be sterilised. It necessarily must be very costly. It occurs to me that inasmuch as bacillus coli and enteritidis exist in abundance, do they not in the body of the normal healthy human being, the addition by means of the external use, or internal use, of water of a few more bacillus coli, or enteriditis, cannot be a very serious thing, can it?—I do not know.

9681. Seeing that they exist already in abundance in the human organism?—I do not know; I should not like to say that you can recognise at once every bacillus coli, or every spore of bacillus enteriditis that you meet, whether it is pathogenic or not. There may be 99 coli, which are, perhaps, harmless, and in the hundredth you might meet with a pathogenic one.

9682. Might be virulent. The practical point for us is to know how far it really would be necessary to urge upon the authorities to go to very serious expense—I estimate that it would be serious—of sterilising their effluents for the sake of protecting the public from germs which you tell us are naturally in the human body, and have a reduced vitality elsewhere?—Well, I should think it is a question of numbers, is it not?

9683. But you tell us, do you not, that in sewage there is a reduced vitality of pathogenic organisms?—Yes, there is.

9684. And I take it that probably when an effluent has got into a river, the conditions are still less favourable to the development of these pathogenic germs?—Well, they might get into a river, and thence into a back-water, and might there find very suitable conditions for multiplying again.

9685. No doubt, in the abstract, the danger exists; but it is a question as to how far it is worth the very grave expense of protecting ourselves against what may be an exceedingly remote danger?—I do not think I could answer that question.

9686. Well, for instance, where a sewage effluent is going into a stream that is quite unlikely to be used

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for drinking purposes, would you consider it at all worth while to sterilise all the effluent?—I think this is more a matter of principle, is it not, to a large extent.

9687. Well, it is a matter, unfortunately, of practice also?—I daresay. Each one case has to be considered on its own merits; but, if you ask me, as a matter of principle, on general grounds, I should think you would have to adopt in all cases the same plan.

9688. It occurs to me—of course, I am not an expert on these matters—that as these pathogenic germs have not a satisfactory habitat in sewage, or in streams, their virulence would probably be considerably reduced by passage through various phases of sewage treatment and into streams, and inasmuch as the coli and the enteritidis exist already in abundance in the human frame the more or less remote danger of the addition of a few to the human frame cannot be sufficiently serious to warrant so large an expenditure as would be required in sterilising. You have not formed an opinion about that from the practical point of view?—No, I have not.

9689. (*Professor Ramsay.*) Have you studied the cellulose destroying organisms at all?—That is to say the bacillus butyricus of Prazmowski; I have not, because I have not been able to obtain that organism in pure culture, nor do I think have others been able to. But I do not think that bacillus butyricus of Prazmowski has that marvellous effect on cellulose which is ascribed to it.

9690. Do you know if that organism is found at all in sewage effluent?—I do not think anybody has found it in it. You mean the cellulose organism of Prazmowski?

9691. The cellulose organism?—No, I am not quite sure whether the bacillus butyricus of Prazmowski is found in sewage, or whether it has got the power of destroying cellulose.

9692. That has not been investigated yet?—No, I do not think so.

9693. (*Mr. Killick.*) I am not quite sure that the questions that Colonel Harding asked you were quite clear to you and to him. I think that what he desired to ask was this: do you think it is necessary to sterilize sewage effluents that go into a stream which is not intended for drinking purposes?—That is not intended for drinking or any other domestic purpose.

9694. For washing?—Or any other purpose.

9695. Any other purpose?—Where is it to go to; is that effluent to remain in the stream or is it to go out into the sea?

9696. To pass from the stream into the sea. For instance, we will take a concrete case. The effluent, we will say, from the Manchester Sewage Works flows into the Irwell, which flows into the Mersey, which flows into the Irish Sea. Do you think it is necessary to sterilize that effluent?—How long would the effluent take to get into a stream of which the water would be used?

9697. It would never be used; these streams are never used?—No; but in the sea it might come into relation with human beings. It would get into the sea perhaps in a few days, would it not—two or three days?

9698. Yes?—Well, it would be in the sea; there people would be bathing or might be bathing; that sea water might indeed be used for watering the streets, for instance, and you might thus transfer it from the Manchester effluent works to the streets of some other place.

9699. But you see that is so very remote, and the difficulty of inducing people to spend sufficient money to sterilize these effluents is so very near?—Well, I am afraid I could not say.

9700. (*Dr. Russell.*) Is the baccillus coli a normal inhabitant of the healthy human body—Yes.

9701. And as so found is it pathogenic?—The bacillus coli, which is obtained from the normal intestine has a feeble pathogenic power; but if there is any disturbance in the alimentary canal, it is a fact, and a very curious one, that you can obtain from such bowel bacillus coli or organisms which correspond in all morphological and cultural respect to typical bacillus coli, which are very pathogenic.

9702. Then in the healthy human being this normally present bacillus coli, what do you conceive is its function?—Well, bacillus coli is a powerful destroyer of proteids, and as it is chiefly present in the large intestine we have a right to assume that it helps to destroy proteids there. It is what one might in a certain sense call a putrefying organism.

9703. So it takes a useful part in the economy?—In the large intestine it does. Very likely in the large intestine; it is not a proteolytic organism like, for instance, proteus vulgaris is; that is to say, it does not produce peptones capable of absorption. The bacillus coli does not do this, but at any rate it does produce some profound alteration in proteids. What the real object of that is in the economy of the body I do not think has been at all shown.

9704. So that you have got in the normal human body exactly the same question as Mr. Killick and Colonel Harding were putting to you with reference to the chance existence of these organisms in water and external to the human body; that is to say, that it is a matter of conditions?—Yes.

9705. Whether harm or no harm will come from the existence of these organisms?—As matter of fact a variety of determining circumstances which have not been investigated are not understood. Just to give you one instance; it has been lately shown on very good evidence that the bacillus coli, when it multiplies in the small intestine is a very harmful organism. Bacillus coli multiplying outside the body, in a test tube, for instance, produces a powerful toxin, a powerful chemical poison, and there is no reason to suppose that when, for some reason or other which we do not know, bacillus coli multiplies copiously in the small intestine, and multiplies very rapidly, that it does not produce within the intestine the same toxic principle; as, for instance, in English cholera. In some cases of English cholera you find in the small intestine an abundance of bacillus coli which in cover glass specimens are found arranged in streaks—*i.e.*, present the "fish-in-stream" arrangement. Recently dysentery has been associated with an organism which is clearly of the type of bacillus coli; the same is also asserted for cases of simple diarrhœa of children. So we must draw a distinction between bacillus coli which normally inhabits the large intestine, and bacillus coli, which has multiplied very largely in the small intestine. What the conditions are which govern the difference we do not know. It would be therefore quite unjustifiable to say of bacillus coli coming from the intestine, that it is a perfectly harmless organism; for a companion b. coli from the same intestine from which it was derived might, if it had had the chance of multiplying in the small intestine, produce those toxic principles which we know bacillus coli does produce outside the body. As a matter of experimental evidence, the bacillus coli of the normal guinea pig's intestine is non-virulent, but the same microbe, when in peritonitis of the guinea pig it passes from the intestine into the peritoneal cavity, becomes highly virulent.

9706. But inside the body all we can do is to consider those conditions. We cannot enter on a crusade to exterminate the bacillus coli, to exterminate it from the mouth to the anus?—No; certainly not. If you say this is a harmless organism which is always present in the intestine, then, of course, I would have you qualify that. I will give you another instance, if you will allow me, namely, the diplococcus pneumoniæ; that is the organism which is associated with and is a cause of croupous pneumonia. That organism is present in 40 to 60 per cent. of normal human beings in their expectoration. Well, you might say that since the expectoration of 40 to 60 out of 100 normal persons contains this diplococcus pneumoniæ, this diplococcus pneumoniæ is therefore entirely to be neglected. Nevertheless it is known that in some conditions, what the conditions are we do not know, this diplococcus pneumoniæ begins to multiply very largely in the bronchial system, and then causes croupous pneumonia.

9707. Does not all that show how very important it is to go beyond the determination of the mere existence of these organisms?—Certainly; that is the very point.

9708. And to consider the conditions under which these become enemies?—Certainly; again, that is the very point.

9709. I take it that this principle which we have been following out on the line of the bacillus coli has numerous illustrations, and the diplococcus pneumoniæ is another?—Yes.

9710. It exists probably in my mouth at the present time, but under certain circumstances it may be become a deadly organism?—Quite so.

9711. Whereas under present circumstances, so far as one knows, it is possibly a beneficent organism?—Whether it has any particular normal function I could not say. Nobody knows that. But there are condition, of time, locality, disposition, and various other circumstances which we do not know, that quite clearly play an important part. What I mean to emphasize is that the discovery of the presence of certain microbes under normal conditions does not warrant our saying: "Well, this microbe is a normal organism, it cannot do any harm, and so on."

9712. I suppose the same law applies to those organisms as to higher organisms, that reproduction only takes place in conditions of very high vitality, abundance of nutriment?—Yes; and various other things that we do not know.

9713. But this variation in the quantity or character of the nutriment not only affects the vitality of the organism as shown by its reproduction, but also affects its character, its individual character?—In its function—its physiological function.

9714. Yes, as regards its function, that is to say an innocent organism may by certain change in its nutriment become a virulent organism?—Yes, that is certainly theoretically quite possible.

9715. (*Major-General Carey.*) On the last page of your evidence you say: "It is therefore desirable, in order to eliminate as much as possible, harmful pathogenic microbes from sewage, to delay as much as possible the passage of sewage effluent into rivers. This is best achieved, and achieved with a double purpose, by slow soakage of the sewage or its effluent through land." You consider that land is the best medium for depriving sewage of these harmful pathogenic organisms?—I think it is a very good medium.

9716. But you say here the best: "This is best achieved." Do you consider that the same result would be obtained by ordinary artificial filters as by passing sewage through land?—Well, as I say, the ordinary filters are not impermeable for organisms, are they?

9717. Not impermeable?—No; they would allow organisms to pass through.

9718. I mean by artificial filters what are known as bacteria filters?—Yes.

9719. I now understand you to say that the organisms would pass through an ordinary bacteria bed, but on account of the slow passage through land many would be stopped?—Well, we do know by direct experiments that these pathogenic organisms have very little chance of survival when passing into land. It is one of the most difficult things to recover from land for instance the typhoid bacillus or the cholera vibrio or other pathogenic organisms; it is one of the most difficult things to recover them when we have passed them into the land.

9720. (*Sir Michael Foster.*) When you can recover non-pathogenic organisms?—Yes.

9721. You think the land has some special influence?—It may be the land by its humus acid or other constituents, and the great competition of other micro-organisms.

9722. (*Professor Ramsay.*) You think they perish, I take it?—They perish.

9723. (*Sir Michael Foster.*) More than the non-pathogenic?—Yes, some of the non-pathogenic can thrive very well in land.

9724. (*Major-General Carey.*) And that you do not obtain the same results when passing the sewage through an artificial filter?—I do not think you do.

9725. (*Sir Michael Foster.*) But the non-pathogenic organisms also suffer, do they not, in passage through a filter?—Yes, but the non-pathogenic do not suffer to the same extent as the highly specialised ones. As regards any organism, the more it is capable of adapting itself to the new conditions as regards selection of pabulum, the more it has the chance of surviving. I suppose that is the general rule.

9726. How does the bacillus coli get into the human alimentary canal do you think?—I know it is there.

9727. Is it in the new born?—Well, it very soon appears. I saw the other day experiments about children, new-born children; for the first few days there was no bacillus coli in the fœces, but very soon it appears. I suppose it must get in.

9728. With the food or drink?—With the food or drink, or some way or other.

9729. Do you think that there is any other mode of entrance than food or drink?—I do not think it is likely. You see it is well known that though the gastric juice is a very powerful influence in arresting the life of non-sporing organisms, there are many conditions under which a non-sporing organism could pass through the gastric juice unscathed. Now, for instance, in milk; experiments have been made with the cholera vibrio in milk. Now, if this vibrio is put into the stomach in water, unless the quantity is enormous, it is likely to be destroyed by the gastric juice; but if it is mixed with milk and put in the stomach a great many living vibrios may escape into the small intestine.

9730. They are sheltered by the coagulation of constituents of the milk?—They are sheltered by the coagulation. We know perfectly well a lot of milk which is not digested in the stomach passes into the small intestine before it is digested; I suppose that is a very feasible explanation.

9731. Then I understand your view to be that the bacillus coli ejected from the human frame, and passing into a stream, although as a rule it is then attenuated, has been virulent before?—It may become attenuated in course of time.

9732. You conceive that there are possible conditions in which its virulence may be revived?—I should think so.

9733. Have you any facts in that direction?—Not, as regards bacillus coli from water.

9734. That is only a general view?—A surmise based more or less on experiments which have been made in a similar direction. It is quite possible to get, under new conditions, an enhancement of the virulence of an organism that had apparently decreased in virulence for some time.

9735. But you have no positive facts?—Not as regards bacillus coli from water.

9736. That would lead one to look to particular conditions to which the stream might be exposed?—No. I have no experiments with reference to this particular matter, though, as I say, there are laboratory experiments in abundance to show that while a particular strain or a particular organism decreases in virulence, when you transfer it to a new medium it increases again in virulence.

9737. Many bacillus coli are ejected from man and pass through the sewage into the stream. Do they die eventually do you think?—Yes, they die.

9738. What do we know about the life of bacillus coli outside the animal organism?—We do not know much about it. They decrease in number no doubt slower than for instance typhoid bacillus. The resistance of bacillus coli is much greater than that of typhoid bacillus, but what eventually becomes of them that of course we do not know.

9739. That we do not know?—That we do not know.

9740. (*Mr. Power.*) Have they a greater tendency to increase outside the animal body than typhoid bacillus?—No, not much. I should think one might take it as established, that an organism which has its natural condition in the animal body would not have the same power of multiplication outside the body, except you give to the organism conditions which in a certain sense repeat those that it had in the animal body. For instance, bacillus coli can grow on our artificial media, of course; there is there abundance of food, favourable temperature, and so on. Well, that is certainly an artificial condition, but still it is to a certain extent a similar condition to that of the animal body: heat, moisture, and plenty of nutriment—suitable nutriment. If you put the micro-organism into a stream you at once cut down its nutriment to a large extent, you diminish the temperature, and very likely you add other conditions which would inhibit to a great extent its power of multiplication.

9741. (*Sir Michael Foster.*) But if it is thrown for instance on mud containing a great deal of humus it might thrive there?—Yes, it might thrive there if organic material be present, and there are not too many competitors; it might thrive there under such conditions.

9742. (*Mr. Power.*) Sufficient temperature also?—Sufficient temperature; yes.

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9743. (*Sir Michael Foster.*) Is the bacillus coli of animals, do you think, the same as the bacillus coli of man?—Well, I think the term "bacillus coli" will sooner or later have to be abandoned, and we will have to specialise more. The term "bacillus coli" covers now what is well known to be a group of organisms, and therefore it is very difficult to say what any one sample has been in the past. In the human subject you get one particular type of bacillus coli, and in an animal you get a different type or perhaps the same type; the diagnostic means we have are very few, comparatively speaking, and we go only by those that we have. We say of a micro-organism, if it shows those particular kinds of colonies in gelatine, if it does not liquefy gelatine, if it produces indol in broth culture, and if it bubbles or produces gas in gelatine-shake, and if it curdles milk; of it we say this is typical bacillus coli communis. If a bacillus coli in all other respects similar shows a delay in curdling milk, or a delay in producing indol, or does not produce indol at all, we say that is another variety. Well, those are all very loose terms, extremely loose, therefore it is better to regard for the present bacillus coli as comprising a whole tribe.

9744. I was wanting to get your opinion on this: Supposing that the organisms in excrement are discharged by the sewage into the stream which is not used for drinking purposes or even for the purpose of cleansing drinking utensils, but yet may be drunk by cattle do you think there is a chance of harm coming back to the human race in that way?—No; I do not see how it would.

9745. You do not think there is risk; you see no possibility of disease coming round in that way?—Well there is one thing perhaps one might mention in this connection, and that is this: There is one particular variety of coli which is known to bacteriologists as the bacillus of Gaertner. Professor Gaertner's attention was first drawn to an outbreak of a severe diarrhœa in persons who had partaken of meat of a calf, which meat did not look normal; and he found in this meat and in the discharges of the patients this particular variety of coli which is called bacillus enteritidis of Gaertner. So you see it is quite possible that the meat or the animal itself when alive might have been infected with a bacillus of this group of the virulent sort.

9746. Was milk in question?—I do not know about milk, but at any rate meat, and this eaten by human beings, caused this severe outbreak of diarrhœa.

9747. You do not think it is possible that there may be organisms which discharged into a river and then getting on pasture and subsequently taken up by the cow in grazing, might appear as pathogenic organisms in the milk of the cow?—I should not like to say anything about the milk in this respect, in respect of coli.

9748. Well I am not saying coli; I am taking the organisms in the sewage?—Oh, yes.

9749. You see I am referring to the danger—the possible danger—of the discharge of sewage into a stream, which is not used for potable purposes; I am asking whether, although you did not use the water for potable purposes, you are secure against danger of propagation of disease; and I put a case where you think it might be possible you might have an organism in the sewage discharged into a river, which, though not drunk by man, might be drunk by a cow, and so be communicated to man say by the milk of the cow if not by the flesh?—Perhaps the diphtheria organism might comply with all these requirements. There are no experiments on record of feeding cows with diphtheria bacillus though there are some on record of inoculating a cow with diphtheria.

9750. (*Professor Ramsay.*) Dr. McGowan tells me that at Norwich sewage farm they saw all the cows drinking the sewage as it ran on to the sewage farm. Would that be productive of harm do you think?—I could not say. I should think it is perfectly possible the sewage might be a means of infecting cows.

9751. (*Professor Boyce.*) You agree, Dr. Klein, that the isolation of the typhoid bacillus is a difficult business, and one which could only be undertaken by an expert?—Certainly.

9752. You regard the bacillus coli as significant of sewage pollution?—The amount.

9753. The amount?—The amount of bacillus coli in your suspended liquid.

9754. You lay great stress on the amount?—Certainly.

9755. You would consider a water which contained a considerable amount of bacillus coli a sewage polluted water?—I should think it surface polluted, yes.

9756. Would you regard the bacillus coli as evidence, as one of our best evidences, of sewage pollution?—That depends of course on the number that are present.

9757. Quite; but if you had a sample of water for analysis and you found a considerable number of the bacillus coli per c.c. you would consider that evidence of sewage pollution?—Of surface pollution.

9758. Of surface pollution?—Oh! most certainly.

9759. Would it in your opinion constitute the best test for surface pollution?—Of those at present known.

9760. In fact you place it above all others as a test of surface pollution?—Bacillus coli and spores of bacillus enteritidis.

9761. These two combined?—Certainly.

9762. You have, of course, made observations on mountain streams and virgin soil, and I dare say there you have not found the bacillus coli?—If there are any farms near, I have found it.

9763. Have you made any observations of moorland upon which sheep are grazing?—I have made observations on moorland where sheep were grazing but there were farms about.

9764. I mention that because where I have made examinations in those cases, and although the sheep were grazing I have not found bacillus coli; and of course it is alleged sheep may give rise on watersheds to considerable actual pollution?—Well as I say there was always some farm or other within feasible distance in the cases I have in mind; at any rate I am referring to waters that I examined from Wales, but there of course there were always farms.

9765. As regards the value of the two tests the enteritidis test and the bacillus coli test on which would you lay most stress, which would you think the most reliable test?—Of the two organisms?

9766. Of the two organisms, as regards surface pollution?—They are always together.

9767. They are always together?—One in much larger numbers than the other.

9768. Which do you consider to be present in the larger numbers?—Coli of course; it is present in numbers varying from 100,000 or 200,000 up to 800,000 and 1,000,000 per c.c., in sewage, whereas bacillus enteritidis is present in less amount, perhaps 100 up to 1,000 or 2,000 per c.c.

9769. As regards their distribution in nature, do you find the bacillus enteritidis more widely distributed say in dust and on grains and foodstuffs, than the bacillus coli?—No.

9770. You do not?—No; I have never found them separate from one another.

9771. Would you expect the bacillus enteritidis to be more widely distributed owing to the fact that it forms spores?—Well the bacillus coli is much less selective in its growth; it is aerobic of course; the other in order to multiply would require anaerobic conditions which it does not find generally in dust or in any other surface, does it? However, I must draw your attention to one point here and that is that not everything that looks like spores of bacillus enteritidis is really bacillus enteritidis.

9772. I am sure the Commission would like to know, at any rate we as experts to the Commission would like to know, what you can tell us as to the recognition of your bacillus enteritidis sporogenes?—I have seen recently, and I am sure Professor Boyce will not mind my saying so, statements, for instance, in reports of the Thompson Yates Laboratory, and also in other papers, which show a not quite clear understanding of what is and what is not bacillus enteritidis sporogenes. Now in sewage and in similar matters, and all matters directly or indirectly polluted with manure or sewage, there are present always particular anaerobes, the spores for instance of the three anaerobes, bacillus butyricus, bacillus enteritidis, and bacillus cadaveris; and it is of importance to identify them. To these three anaerobes I have devoted recently a great deal of time, and among them is one organism which might easily be mistaken for bacillus enteritidis; namely an organism which corresponds to Botkin's bacillus butyri-

cus. Here are two tubes of milk that have been inoculated, one with the pure culture of bacillus butyricus, the other with the spores of bacillus enteritidis. Both these organisms are sporogenous; both are anaerobes; both under the microscope look exactly alike; both produce exactly the same curdling, *i.e.*, the same change in the milk. One, however, the enteritidis, is very pathogenic, while the other is absolutely devoid of all pathogenicity. Now, when testing for the presence of spores of bacillus enteritidis, the usual method is this: One puts the material: dust or whatever the material may be, into milk, recently boiled milk; heat it up to 80° Centigrade, so as to destroy all bacteria except spores; and then incubate it. After incubation, the milk shows the following typical changes: curdling, a separation of whey from the curd. If the culture contains the bacillus enteritidis, a cubic centimetre of the culture injected into a guinea pig causes a profound effect. But if it contains bacillus butyricus alone nothing happens, the effect is nil. If of two such milk cultures in one case you found slightly pathogenic effect from 1 c.c., and in the other case found virulent effect with a like quantity, you might be tempted to say that in the first case the bacillus enteritidis is slightly pathogenic, and in the other it is highly pathogenic. Not at all, for this would be a mistaken conclusion. If you infected milk with dust, or with some other material, and you got this change in the milk, you should make subcultures of the changed milk diluted, and in this way you would be able to separate the two organisms, the butyricus by its colonies, the enteritidis by its colonies. Then if of these pure colonies you make subcultures, you will find one set yields always a non-pathogenic, the other always a pathogenic organism. In many respects the microbes are absolutely identical; but when you come to further investigate them, you will find that physiologically and in some other respects they are very different from one another.

9773. (*Sir Michael Foster.*) In their colonies?—In their colonies. Here are two cultures (*showing them*): a pure culture of enteritidis and a pure culture of butyricus; the one liquefies and the other does not liquify gelatine at all: So that by gelatine culture you can easily differentiate them. Now the bacillus butyricus is an organism which might easily be mistaken for the bacillus enteritidis. And then there is a third organism, that is the bacillus cadaveris, which is non-pathogenic. That is also present both in sewage and in the alimentary canal to a very large extent. Now what I was going to point out to Professor Boyce, if you will allow me, is this, that if you take, for instance, a particle of the intestinal contents, and you put it into the milk, and you produce this typical change, and you do not test it in its purity, *i.e.*, you do not produce first the pure culture from it by dilution; you have no right to say this particle is full of enteritidis. I found when working on this line that the number of spores of enteritidis in the normal large intestine was very small indeed.

9774. Butyricus more abundant?—In some cases more abundant. At first sight it might appear that the intestinal contents are rich in spores of bacillus enteritidis. Take, however, a diseased intestine, for instance, the typhoid intestine, the discharges of the small intestine in typhoid fever, the typical pea soup stool of typhoid fever. You find the number of enteritides enormous, so that under those conditions the enteritidis has multiplied, and so it has also with reference to certain cases of diarrhœa, where you find the number of enteritidis spores in the small intestine very large. Now the enteritidis is a highly pathogenic organism to the guinea pig and other animals. It is at the same time a strongly proteolytic organism; it dissolves gelatine readily; it disorganises muscular tissue. Now if the bacillus enteritidis should find a chance of multiplying within the small intestine, it is impossible to imagine that by this multiplication it would not create what we see it does in the animal body, the guinea pig, a disorganisation of the tissues, or that it would not create these highly toxic principles. Let there be there what I said before with reference to bacillus coli, let there be some condition created in the small intestine by which the bacillus enteritidis becomes enabled to multiply readily, and you would get a very serious condition. That is to say that the presence of a comparatively few spores of bacillus enteritidis, assuming that they had been really recognised as such, in the large intestine does not make this organism a harmless organism. That would be going very much too far.

9775. (*Prof. Boyce.*) I agree with you, Dr. Klein, on the question of the pathogenicity of the bacillus enteritidis, basing it on the comparison of the bacillus coli, and I agree with you about the similarity of the bacillus butyricus and the bacillus cadaveris. The only point is this, it is rather a practical one, our test then of the bacillus enteritidis is by its pathogenicity —the practical test?—The practical test, yes. *Dr. E. F. Klein, M.D., F.R.S.* 2. May, 1901.

9776. So that we should not declare the presence of the bacillus enteritidis unless we had tested it upon a guinea pig?—Yes.

9777. That is definite?—

9778. (*Sir Michael Foster.*) You could not tell it by its colonies only?—I myself can tell it very easily by passing it through these different media.

9779. (*Prof. Boyce.*) But would you deem it a matter that could be put into the hands of anyone but an expert—the cultivation of bacillus enteritidis, I mean?—Not unless he is a bacteriologist.

978. The cultivation of the bacillus enteritidis is much more difficult than the cultivation of the bacillus coli?—To obtain pure culture, certainly it is.

9781. My point was rather this, that in choosing bacteriological tests one should have before one the ease and the accuracy with which they can be carried out. Now it seems to me we cannot ask guinea pigs to be inoculated. There are certain difficulties in connection with that, and therefore I want to know whether you would be prepared to rely for practical purposes, simply with the coli test as apart from the enteritidis test, on account of the drawbacks to the enteritidis test?—I did not quite understand you to say that the test for bacillus coli is so easy that anybody can do it; you require a bacteriologist to do it.

9782. Oh, yes; you require a bacteriologist to do it; but what I had in mind was, say, a chemist on a sewage-works?—Yes.

9783. (*Dr. Houston.*) Might I ask Dr. Klein a question before he answers, as it is hardly fair, I think, that he should be asked to directly answer Professor Boyce's question until I put it from a slightly different point of view. You said, Dr. Klein, just now that the test was a difficult one; but you meant, did you not, that to carry it out in the elaborate way that you are accustomed to, it requires a great amount of skill. Nevertheless, purely to determine the change in milk is as simple a test as you could possibly have, is it not?—Yes, that is very easy.

9784. Have you not found, when adding sewage or sewage effluent in small amount to milk, you get this "change," but do not, on inoculating the whey of the altered milk into the animal, get virulence; that if you use a larger amount of the same whey for inoculation of an animal you do then get virulence?—Certainly.

9785. So that as a matter of fact in practice you could have very good grounds for believing that if you do get this peculiar "change" in milk, you will probably also get the virulence, if not with the amount ordinarily injected, at all events, if injected in a slightly larger amount, or if a somewhat larger quantity of the substance under examination be used in making the milk culture?—That is so, I think, with sewage.

9786. I am speaking of sewage, of sewage effluents solely?—In sewage and sewage effluents if you have this change in milk it is very likely produced by butyricus and enteritidis; they are always associated.

9787. So that if an unskilled worker was working with them, and with, say, $\frac{1}{100}$ c.c. he observed this "change" in milk culture which would be the usual thing, would it not, with sewage?—Yes.

9788. If he got this change in the milk he might assume that in 90 per cent. of those cases it would also be virulent?—I should say so.

9789. He might assume that enteritidis was present in 90 per cent. of the cases in which the milk became changed?—Yes.

9790. So that in a sense it is a very simple test?—Yes; it is not more difficult than the coli test.

9791. Would it not be rather more easy in the sense I have indicated?—Yes, because in 24 hours you would have the observation completed.

9792. (*Sir Michael Foster.*) Your position is this, that the action on milk may be due either to the butyricus or to the enteritidis; yet that, when used as a test of sewage contamination, since the butyricus is almost

Dr. E. B. Klein, M.D., F.R.S., 22 May 1901.

always accompanied by enteritidis, the change in the milk is a proof of the presence of enteritidis, although it is not due to enteritidis alone?—Certainly.

(*Professor Boyce.*) That is interesting; I am glad to hear that.

9793. (*Sir Michael Foster.*) Are they never dissociated?—Well, I always find them associated in sewage.

9794. As a practical test you would be quite content?—Oh, yes.

9795. (*Professor Boyce.*) Without inoculation?—Well, for myself, if I had to give a definite opinion I should certainly inoculate.

9796. (*Sir Michael Foster.*) That is to say, you do not trust the reasoning I put before you just now?—For my own satisfaction I think I should go on to inoculate in order to make quite sure.

9797. The other is a small assumption, and to get rid of even that small assumption you would inoculate?—If anybody showed me two tubes of milk culture typically changed, and he said I got that by putting in a certain small quantity of fluid in the milk yesterday, and look here to-day; well! I should say this is very likely butyricus and enteritidis. It is very unlikely to be butyricus only, and it is also unlikely to be enteritidis only. I should say it is more likely butyricus and enteritidis together, and if he told me that he got this with a small quantity of fluid which was sent him for examination, I should say that the fluid is clearly surface pollution, but I should advise him, in order to make sure of its being enteritidis, to inject a cubic centimetre of the whey of the typically changed milk culture into a guinea pig.

9798. (*Professor Boyce.*) For the last year I have examined every sample of milk, shellfish, and grain in my laboratory, and I have simply returned enteritidis by the naked eye test; would you say that was correct?—If you published that in a scientific paper I should say that is not sufficient. If you published it for the object of showing that Klein is wrong, I should certainly say that is not sufficient. If you published it with the object of showing that the organism in your culture is a very virulent organism and produces diarrhœa, is connected with diarrhœa, then I should expect you to show me how many of these samples had the real enteritidis.

9799. But you would not deduct anything from that, or that the reaction indicated surface contamination?—Milk that is not exposed to pollution does not give that test.

9800. The bacillus coli is usually there at the same time?—Certainly, this is always the case.

9801. Given then the enteritidis reaction in milk, and side by side the coli reaction, would you say that that was presumptive evidence of contamination?—Certainly! But it has to be borne in mind that the contamination need not, necessarily, have been direct, since alike in a farm or in a town dust particles are liable to be associated with these micro-organisms.

9802. More than milk, yes, but that is my point; I wanted simply to know whether you think that the milk reaction side by side with the coli reaction would do away with the necessity of doing the guinea pig test?—Well, I must only repeat, if I have to give an opinion about the presence of it, I should certainly do the injection.

9803. There is one other point, and that is in a paper here by Balfour Stuart. I notice that he examined a large number of cases of grains, and he says: "From the above 60 samples, 41 gave an enteritidis growth in the milk; of these 30 were fatal to guinea pigs. . . and 11 were pathogenic, but non-fatal." Now do you think for grains that that is a large percentage of pathogenic spore bearing organisms?—How many grains did he use?

9804. Altogether he did 60 samples; most of them were grains bought in the shop?—How much did he use in each experiment?

9805. Half a test tube almost, quite a gramme?—For each?

9806. For each?—You would get it, but in a very small quantity of the grain he would not get it.

9807. But in those same experiments he tested for the bacillus coli, and we did not find the bacillus coli?—The same amount.

9808. Yes; we have over and over again tested these grains for bacillus coli?—Half a test tube of grains giving the test of bacillus enteritides and not the coli?

9809. Bacillus enteritides and not the coli. A gramme say, put it at a gramme?—I do not know that this is not exactly what I found in similar experiments.

9810. But would you not expect it from the fact that the coli would die in the dry rice, while the enteritides would live?—Yes. The spores of enteritidis would remain alive, while many, but not all, bacillus coli would succumb.

9811. That would be the explanation?—Yes.

9812. (*Chairman.*) I just wanted to ask you one question. As far as I understand, you consider that the microbes come to an end from being kept in uncongenial surroundings, and that the longer they are kept in these uncongenial surroundings, the more of them come to an end?—Yes, I think so.

9813. Therefore if you had as much artificial filtration as you have with ordinary land filtration, as long as the quantities were equal and the time that the microbes were kept in uncongenial conditions was equal, the results would probably be equal?—They might be the same, yes.

9814. You have no reason to suppose that they would not?—Are you speaking, if I may ask, of pathogenic organisms?

9815. Yes; I mean any organism would live a shorter time in uncongenial conditions than it would in congenial?—Certainly.

9816. Then have you ever made any experiments in the destruction of organisms, pathogenic or otherwise?—Oh, I have made a large number of experiments with various disinfectant substances under various conditions.

9817. And have you found anything suitable for destroying them, any means by which you could destroy the organisms and sterilize an effluent?—Heat is the best agent.

Dr. W. WILLIAMS, M.A., M.D., D.P.H. (Oxon.), M.R.C.S., F.C.S., etc., Medical Officer of Health to the Glamorgan County Council, called in; and Examined.

Dr. Williams, M.A., &c. 21 May 1901.

9818. (*Chairman.*) You are Dr. Williams, I think, the Medical Officer of Health to the Glamorgan County Council?—Yes, my Lord.

9819. Speaking from the point of view of the Medical Officer of Health, will you give us any general views you entertain on the subject of sewage disposal?—I was appointed Medical Officer of Health to the Glamorgan County Council in 1892, and for some time previous to that date I acted as Assistant and Deputy Medical Officer of Health for Shropshire. The Sanitary Committee of the Glamorgan County Council have taken up the question of sewage disposal with great energy throughout the whole county, which has an estimated population (including the Boroughs of Cardiff and Swansea) of over 900,000. Different to most counties in the kingdom, all the Glamorganshire rivers have practically their origin inside the county, or in the mountainous regions of Brecon or Carmarthen, immediately adjoining its northern boundary—so that all pollutions of rivers that the County Council has to deal with are occasioned within the county. (All the Glamorgan rivers trend towards the sea, into which, after a short course, they discharge their contents.) In the whole county there are 30 sanitary districts, and out of these, 13, representing a population of some 516,000, discharge their crude sewage into tidal rivers, estuaries, and the sea, and the sewage of some nine districts, or parts thereof, are treated on sewage farms, of which there are several, large and small, and one of the oldest (Merthyr) in the county; at present their number is about 20, and in the course of a few years we shall have several additional ones. Systematic inspections of all sewage works and farms are made by myself, and since the establishment of our County Public Health Laboratory some 18 months ago, samples of sewage effluents and rivers waters have been collected and analysed there. Through the action of the County

Council, several old sewerage works have been improved, and many new works constructed, and when the works now in progress are completed, the expenditure on these works will reach about £500,000. Several bacterial tanks also are being put up in various parts of the county. As the result of personal observations and experience, I have arrived at these conclusions:—

1. That the treatment of sewage on suitable land is satisfactory, provided the areas are properly supervised, which is not always found to be the case.

2. That in several of our long, narrow, and crooked mining valleys it is impossible to acquire a sufficient area of suitable land within a reasonable distance, except in very large centres. (The county of Glamorgan is peculiar in this respect, and is made up of a system of valleys running north and south, and all opening on the sea, or the flat land, known as the Vale of Glamorgan, to the south of the southern crop of the South Wales coal basin.)

3. That, as far as my experience goes it would seem to have been proved that the whole process of sewage disposal can be effected by biological methods (my experience in this direction is very limited).

4. That it is necessary to arrive at an authoritative opinion regarding the various biological methods recommended.

5. That, in this county, at any rate, greater progress would have been made in purifying our rivers had not the Local Government Board insisted, under all circumstances, on the hard and fast rule of land treatment, in addition to artificial filtration. At the moment, progress on this account is at a standstill in several districts (*e.g.*, Glyncorwg).

6. That it is important to have as many joint sewerage districts as possible in such a county as Glamorgan, for here there are many districts situated in the watersheds of the same rivers (*e.g.*, Rhondda, population 123,000; Pontypridd, 40,000; Aberdare, 48,000; Mountain Ash, 30,000; Merthyr, 70,000; and parts of others, all in the Taff River watershed).

7. That the inspectors (holding sewage inquiries) of the Local Government Board should be well acquainted with the physical features of the districts in question as well as of the neighbouring districts, especially those in the same watersheds.

8. That the few but comprehensive joint sewerage schemes in this county are a great success (*e.g.*, Rhondda Merthyr joint schemes).

9. That no crude sewage should be discharged into the sea, except after the most careful consideration of all local circumstances, and after careful experiments made with different float materials, as to the directions of the currents at various conditions of the tide (*e.g.*, Ely and Rhymney rivers).

10. That similar experiments and examinations of the water (chemical and bacteriological) should be made in the case of tidal rivers and estuaries.

11. That the manufacturing refuse from tin plate works, which are very common in this county, should not be allowed to be discharged into rivers untreated. (1) The "Pickle" fluid should be treated in suitable tanks by evaporation and re-evaporation until all the H_2SO_4 it contains is converted into copperas ($FeSO_4$). (2) And the "swilling fluid" passed through broken lime stones (frequently changed) and through filters of earth, roots, and branches of trees, etc. Water containing vitriol and sulphate of iron from tin works are dangerous to human beings and animals, and most fatal to fish. (*Show samples of dead fish from Ely river.*)

12. That the suggestion that a uniform standard of purity of sewage effluents should be established, is not a practicable one, the local circumstances, which should be taken into account, being so different.

13. That the extent to which storm water shall be dealt with in sewers is very important.

14. That it is very desirable that the present legislation procedure, with regard to rivers pollutions, should be simplified.

15. That crude sewage discharged into rivers with towns or villages on their banks lower down, is dangerous to human beings and animals, and often the cause of nuisance.

16. That the Government should countenance the establishment of health laboratories, where sewage, effluents, manufacturers' refuse, and other materials discharged into rivers, estuaries, sea, etc., could be thoroughly and systematically examined if, and when required, and that these should be under the control of County Councils.

In the first place I have told you that a large sum of money has been expended recently on works of sewerage and sewage disposal in the County of Glamorgan. I ought to have specified a time, I mean within the last eight or ten years. There were some big works commenced when I went there, but I speak mostly of the last eight to ten years. When all these works—the works commenced in the last ten years—are completed, there will have been expended on sewerage works and sewage disposal in the county a sum of about £600,000, which is a fairly large sum. The population of the county is about 900,000 at the present moment, and the increase has been very great indeed. The population in the county increases at some places very rapidly indeed, owing to coal pits being sunk, and people coming to work there. I have found in the county of Glamorgan that the treatment of sewage lacks supervision. I find that this is frequently the case, I could give instances, if required, showing that sewage farms are not as a rule under proper supervision.

9820. (*Sir Michael Foster.*) That is to say the sewage farm, the land of which is suitable is not properly looked after?—Is not properly looked after; that is my experience in the County of Glamorgan.

9821. (*Mr. Killick.*) Is that in the cases where the sewage farms are let to tenants?—Especially in those cases.

9822. (*Colonel Harding.*) There is no supervising authority such as a Rivers Board or anything of that kind there?—We have in one instance only a supervising authority, a joint sewage farm committee for Merthyr and Aberdare. That is properly looked after by a servant of that Board. No we have no Board such as you have described. In several of our long narrow and crooked mining valleys it is impossible to acquire a sufficient area of suitable land within a reasonable distance except in very large centres. Well this is in my opinion our great difficulty in the County of Glamorgan, the difficulty that we experience in getting land. Of course if any of you have seen the valleys they are very long, very narrow and crooked, they are very narrow indeed some of them. I could instance a valley in the county called Glyncorwg; it has three centres of population about a mile and a half from one another, and in that district they have a population of 5,000 people, and it is impossible to get land; they cannot get land at all for sewage disposal purposes there, and the only thing to do there is to take it down to the sea which is about 10 miles away, and to take it down to the sea would mean a tremendous expense, more than the District Council could bear. The consequence is they have done nothing there though they have been pressed by the County Council to stop polluting the streams. The other day I advised them myself to get their surveyor to prepare a scheme and submit it to the Local Government Board for their sanction, and in this scheme which is approaching completion is shown a biological tank of some description or another and the effluent passing into the river. This will be placed before the Local Government Board, and of course they can say yes or no to it. But this is not the only instance in the County of Glamorgan. There is a very important valley, a mining valley called the Rhondda Valley. They found it impossible here to get land; there was no land to be had except very near the sea. What they did here was: several authorities joined; two large authorities; they were near a population of 120,000, it is now, and the other one has a population of 40,000. I refer to the Rhondda and Pontypridd authorities. They joined and had a joint sewerage scheme, which costs them about £250,000. That works admirably.

9823. What is it—a land scheme?—No, into the sea.

9824. Oh, into the sea?—Into the Bristol Channel.

9825. (*Sir Michael Foster.*) What distance is it carried in that case?—The highest point would be about 30 miles.

9826. By gravity alone?—Yes; the highest point would be about 30 miles from the Bristol Channel. We have another joint sewerage scheme which I mentioned, viz., Aberdare and Merthyr and Mountain Ash, but in my opinion we ought to have many more of them in the County of Glamorgan. That is No. 2; the difficulty of getting land there is very great indeed.

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No. 3: I have had very little experience with biological tanks. We have only two working now in the county, but there are about half-a-dozen in the course of construction. They are biological tanks, some septic and others uncovered. No. 4: the local authorities when considering schemes of sewerage for their districts are very undecided as to which scheme to go in for, whether the septic or any of the other biological schemes, and as far as I am aware there is no authoritative opinion regarding the various biological methods recommended.

9827. (*Major-General Carey.*) Where do they expect to get that from?—Well they have been looking for it all round the country. I say there is not one. They find a difficulty in fixing upon any particular biological method. I said at No. 5 that in some respects in the County of Glamorgan the matter of sewage disposal is at a standstill, because land is insisted upon. I have mentioned one district—Glyncorwg—and in the Rhymney Valley they have found great difficulty to get land, and they have not got the money to go down to the sea.

9828. (*Sir Michael Foster.*) They are doing nothing at all; they are discharging their sewage into the river?—In some parts they have done a great deal, but in some not much.

9829-30. In those cases they are discharging the whole of their sewage into the river?—The whole of it—yes.

9831. Have you not taken any steps against them through the County Council?—Yes, we ask them to stop polluting the river, and they say, "What are we to do?" Respecting this very district we made representations to the Local Government Board about five years ago, and we ourselves visited the place very frequently indeed, and they said, "We are preparing now a scheme which will be submitted to the Local Government Board, showing biological tanks and no land," and they say, 'We can do no more."

9832. You have not taken proceedings against them?—No, sir, we have not; no, not against Glyncorwg. We have taken proceedings against some. No. 6. That it is important to have as many joint sewerage districts as possible in such a county as Glamorgan. We have two or three very large ones. Then I come to No. 7; that inspectors of the Local Government Board who hold these inquiries, etc. Well, I will instance a case in the Rhymney Valley. We as a County Council had been advocating a through system of sewerage for the Rhymney Valley, but the local authorities themselves would not hear of it, and they did not hear of it, so they went in each one of them, except one, for a system of their own. In one district I remember an inspector of the Local Government Board came down and held an inquiry as to whether the scheme was a proper one or not, and I remember very well that in this case there was a great difficulty in getting suitable land, but they had land at last, and they had to pay very much for it. On a second occasion there was an inquiry again concerning the same sewerage scheme in the same district. Another inspector came down. Going up the Valley I remember two inspectors holding inquiries at Caerphilly, and higher up again I remember holding two different inquiries at Rhymney. We had always been advocating a through system of sewerage in these places for this very Valley to the sea. That did not come to pass, but they had a sewerage scheme of their own, and I am afraid they are going to be failures. The valleys are so narrow and increasing so rapidly in population, and very probably where the sewage farm in one instance is now, they will be clogged up very soon.

9833. (*Major-General Carey.*) The Local Government Board has no power to make authorities combine for sewerage schemes?—No, but there is a power in the Public Health Act. In the Public Health Act they could combine for sewerage purposes.

9837. It is not a compulsory power?—No, I know that. We have been advocating it, but systems of sewerage for these valleys—combined systems—would, I think, be very useful. That no crude sewage shall be discharged into the sea except after the most careful consideration of all local circumstances, and after careful experiments made with different floating materials. I can instance here a case near Cardiff. Floating experiments were made not long ago in connection with a scheme which the Cardiff authorities are about to carry out—a sewage scheme. At the present moment the sewage of Cardiff is discharged into the sea or into the Bristol Channel at several points, so there is a nuisance produced on the sea shore. Penarth is another small town by the side of the river. The sewage of Penarth is also discharged into the Ely, a tidal river, and into the sea at four different places, and this also produces a nuisance on the Penarth beach.

9835. I do not think so?—Well, I do, sir.

9836. I walked very carefully along the Penarth beach?—I think so myself.

9837. I did not see any sewage?—I saw sewage there myself. I could point it out to you. I know the place very well—I live there.

9838. Very well?—Well now, the Cardiff people are contemplating a scheme which I think is a very good one; to take out the outfall sewer far beyond Lavernock Point, as you may know, sir, and to discharge only 1½ hours before high water and 2½ hours after high water, a thing which ought to be done for Cardiff and Penarth, but as carried out now I think myself it is a nuisance. That is why I think it important to make float experiments. We made float experiments also on the river Ely. I was there for many days, and I found that some small oranges drifted up about as far as one mile below Leckwith Bridge, and that the water showed evidence of sewage contamination even there. I do not know whether you would like me to say anything of refuse from the tin works of which we have very many in the county, that is No. 11, that the manufacturing refuse from the tin plate works which are very common in our county, should not be allowed to be discharged into rivers untreated, and I think that the "pickle" should be wholly converted into sulphate of iron (copperas). With regard to the swilling fluid——

9839. (*Sir Michael Foster.*) What is the swilling fluid?—The pickle.

9840. Yes?—It is sulphate of iron and vitriol.

9841. The swilling?—There is very little vitriol in it and a very slight amount of sulphate of iron—very little indeed. They simply dip the iron into it to clean it from the acid; the pickle is very injurious.

9842. (*Colonel Harding.*) It is saturated solution, the pickling fluid?—Yes.

9843. It is very faintly acid?—Yes, very faintly acid.

9844. And you suggest that it should be put in connection with lime?—Yes, limestone. Yes, they do that in most places, and the pickle is converted into copperas by evaporation and re-evaporation.

9845. Is there any attempt made in your neighbourhood to evaporate the iron liquor so as to obtain the crystals?—Yes, I say that here.

9846. But is there an attempt made elsewhere?—Yes, in nearly all cases.

9847. They do it?—They do it in nearly all cases.

9848. There is a liquid residual which is strongly acid, which probably they put into their vats and re-evaporate it so there is no reason why this strong pickle fluid should be lost at all, it should be converted into sulphate of iron.

9849. It is perfectly practicable?—Perfectly practicable; there is no hardship.

9850. Are you insisting on that being done?—Yes.

9851. That is a case which admits of being dealt with, if not at a profit, with such results as would pay the cost of the treatment? What does it cost to make a ton of this?—8s.

9851*. What do you get for it?—Between 8s. and 9s.

9852. That is about the cost?—That is about the cost, yes.

9853. That is a source of pollution you have the power to stop?—But it would be a hardship to have to try and do the same with swilling fluid, which is only slightly acid.

9854. You could obtain the same result by passing it over limestone?—Yes, but there is a little difficulty in getting the changes in that. But still we do not get very much trouble with these now. As to the standard of purity, our rivers have very little water in them in the summer. In winter they are very high. No standard of purity of sewage effluents would do much good as far as we are concerned. Of course, there is a very rapid fall in some of them.

9855. (*Mr. Killick.*) I suppose you would say that no effluents should go into the stream which are putrefactive?—

9856. You would say that?—I would say that, certainly. We hope, after all these sewage works which are now being carried out are completed, to have very little indeed poured into our rivers. Some time ago we took proceedings against a tin works—the Cynon Tin Works at Aberdare. The County Council gave them six months' notice, and by the time the inspector came down there was no pollution. A few days before there was pollution, and a few days after he was gone there was pollution there, so we found it rather difficult to take any effectual proceedings against tin works because of the six months' notice. We found it so in the case of these tin works at Aberdare. There was no pollution at the time the inspector was there; there was pollution a few days before and afterwards.

9857. It is an offence to pollute at all?—Yes.

9858. One pollution would establish your case?—We failed to establish the case there because at the time the inspector held the inquiry there was no pollution.

9859. You had no evidence of pollution?—We had evidence before, but at the time he was there there was no pollution taking place.

9860. (*Colonel Harding.*) Can you give me an instance where the iron liquor has been successfully treated on a considerable scale for the production of copperas?—Yes. sir, it is prepared at Pontardawe, at Mr. Gilbertson's works; that is one place I remember.

9861. On a considerable scale?—On a considerable scale.

9862. (*Sir Michael Foster.*) What is the market?—I could not say. It is also prepared at Caerphilly; it is also prepared at the Ely Tin Works, at Llantrissant, and in many of the tin works in the Tawe Valley—most of them, in fact. I believe I would be right in saying there is only one in the Tawe Valley where copperas is not prepared.

9863. (*Professor Ramsay.*) What is the process—evaporation and re-evaporation?—Evaporation and re-evaporation with scrap iron, nothing else. But the great difficulty I find there, as I said before, is the land problem, and local authorities do not have the means to carry the sewage down to the sea.

9864. (*Major-General Carey.*) Do you know Ogmore and Garw?—Ogmore and Garw, they are polluting the river now, polluting it to the great annoyance of Bridgend lower down, and they have done so for years. I should not like to say exactly that the typhoid fever which happens at Bridgend annually in the autumn has anything to do with the sewage in the river; I should not like to say, but I will say this—that the river has a most offensive smell in summer.

9865. (*Sir Michael Foster.*) What is the fever which occurs?—Typhoid fever, sir, regularly every autumn. We have not been able to find the cause of it. The drinking water is absolutely pure, but the river is most offensive, and at Ogmore and Garw, the district you mentioned, they have not yet carried out a scheme of sewerage.

9866. (*Professor Ramsay.*) Are there any exposed mud banks on the river?—In which of the rivers?

9867. Where you get the typhoid fever outbreaks?—No, sir, I do not know of any.

9868. (*Sir Michael Foster.*) Have the fish been killed in the river by means of the pollution?—By the sewage?

9869. Yes?—I am not aware whether fish have been killed in the river by the sewage, but fish were killed three or four years ago by probably the disinfectants which were used at Bridgend, so we supposed fish had been killed in the Ely river. I did intend to bring samples in a bottle, but I could not get at them. They were not kept very well. When the pickle was turned into the river, as was done in the case of the Llantrissant Works, the fish were killed in great numbers, and a few of them were collected.

9870. (*Chairman.*) I think you told us that you have had very little personal experience of artificial filtration?—Very little, my lord.

9871. So that you are not able to compare its results?—They are really all sewage farms and sea sewage disposal works down there except one and a few that are being constructed now.

9872. (*Colonel Harding.*) And we understand that in your district there is no land available on account of the narrow valleys, that it costs too much to take it a long distance to the sea, and therefore if any system of artificial filtration is found to be practicable it would be very useful in your neighbourhood?—It would be most useful indeed in most of our districts. In many of our districts it would be very useful indeed; in fact, that is the only method that would suit most of them.

9873. (*Chairman.*) Have you any experience as to cottage sewage, where there is no water carriage or anything of that kind, what a man who lives in a cottage does with his sewage?—Yes; take a typical district in the Vale of Glamorgan—a purely agricultural district. Well, in a cottage in this district—a working man's cottage, for instance—there would be a very large garden; that is nearly always the case, and there would be a receptacle—a bucket or a pail—above ground. I have insisted upon that, and the contents of it are regularly buried in the soil of the garden, the garden being very, very large.

9874. (*Sir Michael Foster.*) Every day?—No, not every day; every time it is full—say about once a week. That is the system in that district, and in individual cottages like that it is found to answer very well, but in the case of larger villages the difficulty comes in where the gardens are smaller. Where you get plenty of land it will do very well—that is my experience.

9875. (*Major-General Carey.*) And in all these cases is the water supply from the wells?—Yes, some of them.

9876. Close to this land on which your sewage is deposited?—Not very close. In some cases it would be, but they have all been properly protected now, and but they have all been properly protected now, and are being analysed once a quarter now—examined thoroughly.

9877. (*Sir Michael Foster.*) Bacteriologically?—An chemically, sir, at the County Laboratory, and we have found a good many polluted.

9878. (*Colonel Harding.*) How do they deal with slop water in these cases?—That is the difficulty, of course. Well, they deal with that on the soil of the garden. In some instances drains conduct the slops into a neighbouring field, and it is used for broad irrigation there; but I think in the case of an individual cottager with a big garden and a field about him there would not be very much difficulty if the people are clean and careful.

9879. (*Chairman.*) Is it common to have a pail or a pit in the closet? Do they have a pit or a pail?—Well, in the districts that I am speaking of it is common now to have the pails, because the local authorities some years ago have insisted on doing away with the old cesspools, and successfully so. I think myself that that is a very good movement.

9880. I suppose you do not see any objection to a small pit, do you, if it is kept cleaned out with tolerable frequency?—No, I do not if it is properly built.

9881. You mean underneath the closet?—I do not like them at the best of times. The difficulty is keeping them clean. I would much prefer to get a receptacle above ground. That is what I have been advising all the time. I do not like cesspits however good they are, however well built they are, because there is the difficulty about cleaning them out, and people are careless.

9882. The pit I contemplate is a brick and mortar pit, built rather above the surface of the soil?—Rather above.

9883. The floor of the pit is to be a bit above?—I have no objection to that. The pit I meant was an underground pit.

9884. I mean where the floor of the pit was above the surface?—I have no objection to that.

9885. You have no objection?—Provided it is properly built and does not allow of any soakage.

9886. If it is properly built it is a matter of no consequence whether it is a pail or whether it is a pit?—Not if it is properly kept and properly emptied.

9887. Then it may be left to the habits of the people to have either?—That is what it is.

9888. (*Major-General Carey.*) And if the contents of this pit, supposing it is above ground, are not regularly removed by the occupant, I suppose a nuisance is created, is it not?—Yes, there is no doubt.

9889. Sometimes the authority take it upon themselves?—Sometimes they do, but as a rule they find it

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very hard work in scattered districts where you find these things, and it is pretty nearly always left to the occupier, and if he does not do it it is a nuisance.

9890. (*Colonel Harding.*) And do you think that superintendence is impracticable in these rural districts, that you are absolutely dependent on the occupier, and if he does not do it—— ?—No, you are not absolutely dependent on the occupier; there is the sanitary inspector. As it is, they do go round every house so many times a year, and they very soon find out who are the people who are negligent.

9891. And you find that kind of supervision is sufficient to keep it right?—Well, it is not sufficient, but it is of great utility. In a very wide district it is very difficult for one inspector to do all this work. The villages are very far apart, and it is very difficult for him to visit each village as frequently as he would like, so that in his absence they go wrong occasionally. A great deal depends on the people.

9892. (*Major-General Carey.*) And if the cesspit is not properly emptied or irregularly emptied, of course you may have an overflow of polluting sewage into the nearest stream?—Yes.

9893. (*Professor Ramsay.*) I see in No. 16 you suggest that the Government should countenance the establishment of health laboratories where sewage, effluents, manufacturers' refuse, and other materials discharged into rivers, estuaries, sea, etc., could be thoroughly and systematically examined if and when required. and that these should be under the control of County Councils?—Yes.

9894. Where would you propose to have those?—Tho Glamorgan County Council established a public health laboratory in Cardiff.

9895. In some central town?—Well, in the most central and convenient town of the county.

9896. (*Sir Michael Foster.*) In connection with the college?—Well, ours happens to be near the college, in a building owned by the college, but the college has nothing whatever to do with the Glamorgan County Council. We rented this house from the college, because teaching in connection with this place was contemplated, and it has taken place since, so it happens to be by the college, although the college has nothing to do with it. We established this laboratory after a good many years talking about it. About eighteen months ago the thing was done, and we took the building and we pay £40 a year rent; we extended it, and we provided the requisite apparatus; one part is a chemical department, and the other is a bacteriological department, and the County Council have last January twelvemonths appointed a bacteriologist, and since then they have appointed an assistant to him.

9897. (*Professor Ramsay.*) Is it under the control of the County Council?—Yes, it is under the control of the County Council, but some short time ago the Corporation of Cardiff joined the Glamorgan County Council in this matter, and we find that it is working very well indeed. I should like to have an opportunity of saying what we do there. We examine there once a quarter every public water supply in the County of Glamorgan, chemically or bacteriologically, and we also examine well waters from these rural districts that I am talking about in the county. We have pretty well examined every well by now. We have been working eighteen months, and every well that the district Medical Officer of Health or myself suspect we get samples of in addition to the public wells which are done quarterly. I think this is a movement in the right direction myself.

9898. When you find bad water in a well what is your course?—We have found many bad waters. We write to the Medical Officer of Health; we send him a copy of the analysis and keep one ourselves, and we say "the water of a certain well has been found bad, will you make this known to your local authority," and he does, and the necessary steps to have the well closed are taken. We have found that to be very useful indeed; at the end of six months' work we pick out every supply that is polluted, and send a letter to the local authority. If they did not take proceedings we can see that they do. I think that under the Public Health Act County Councils have no power really for establishing laboratories. This was established under the Technical Instruction Act.

9899. Then in No. 14 what bye-laws would you suggest for simplification of procedure?—Pollution arising from works where one must give six months' notice to the authority that pollutes, are those where we found difficulty—for instance, tin works.

9900. Would you suggest that there should be a shorter notice given?—We have not found it practicable. As I said before, when the inspector came the pollution was stopped.

9901. There was no pollution?—There was no pollution, and we could not get a conviction, and though there was no pecuniary loss to them at all, only they would not provide proper plant. They do so now.

9902. (*Sir Michael Foster.*) I suppose the storm water itself is very pressing in Glamorgan?—Very pressing indeed. The storm water in the County of Glamorgan is enormous at times. We have a great difficulty in this big joint sewerage scheme of the Rhondda Valley and Pontypridd to keep it out, and they have failed to keep it out, whereas in summer the water is barely enough to wash for flushing.

9903. (*Dr. Russell.*) I see in No. 15 you speak of crude sewage discharged into the river being dangerous to animals?—Yes.

9904. What evidence have you got of that?—I remember having evidence once—I do not know whether it is right—of a cow drinking a sewage-polluted water and became ill and threw her calf, and I have had many a complaint from farmers along the banks of the Ely that the cattle do not seem to care for the sewage-polluted water, though I know from my own experience that cattle really like standing water to drink, whereas horses do not.

9905. It would be chemical sewage though, trade refuse?—Yes. in the River Ely, tin works refuse.

9906. In this, might there not be some mineral poison?—Oh, there was mineral poison as well as sewage in it, and it will kill fish without a doubt, the pickle will when they put it in the river.

9907. And you say it caused abortion in this cow?—I believe it caused abortion.

9908. Did any action for damages ensue?—I do not think so.

9909. Is that the only instance you have?—That is the only instance I remember except the general complaints about horses and the cows not liking the water, but I do not remember of any death being attributed to any sewage or manufacturing refuse.

9910. You spoke, I think, about a village where typhoid fever had broken out?—At Bridgend.

9911. You attributed——?—No, I should not like to say that I did attribute it to the pollution of the river, but we could not attribute it to anything else, the river was in a filthy condition. I hope it will not last long, because the polluting authorities up in the valleys, with the exception of one which was mentioned here, are carrying out schemes of sewerage. Typhoid fever has been there, every autumn for many years since I have known the place, and we certainly cannot attribute it to the water supply and the drains, and the sewers there are good, we cannot attribute it to anything else, but I should not like to say that it was caused by the pollution of the river.

9912. Then there is pollution? You said to Professor Ramsay there are no mud banks?—There are no mud banks within some miles of the town; there are sand banks lower down, but there are no sewers near them at all.

9913. It is simply moving?—There are no mud banks on this river so far as I know.

9914. Then what did you do to deal with this enteric fever?—Well we had an hospital built there, and we made a house to house inspection of the place, and we analysed the waters systematically, both chemically and bacteriologically, and we could not find anything wrong with any of them. We had a disinfecting apparatus there—an apparatus for disinfecting infected bedding, clothing, etc.

9915. Have they waterclosets or privies?—Waterclosets, all flushed, but we have not done away with the typhoid fever yet; we have it every year.

9916. It is most extraordinary?—I am very sorry to say it is well known—the case of Bridgend. It is well known at the Local Government Department.

9917. What is your general opinion of the farms which you have examined there? On the second page

of your statement you say that the farms have been examined by yourself?—Yes.

9918. For many years past?—Well, ever since I have been there—about eight years.

9919. Can you give any general opinion as regards their action; do they do well or are they efficient in purifying the effluent?—Well, I cannot give a very decided answer, because it is only within recent months that we have commenced with the effluents; we have only had this laboratory for a short time; but my experience is when a farm is under the control of an official of the local authority it is very well looked after; when it is left to a farmer it is not well looked after; that is the rule. Of course, when the farmer does not want the sewage he passes it into the river; when he does want it he puts it on the land, which is not all the year round.

9920. (*Major-General Carey.*) Do you know the farm of Merthyr?—Yes, sir, I do, very well. *Dr. Williams, M.A., &c.* 21 May 1901.

9921. Do you know what population they are treating—what proportion to the acre?—I know the population.

9922. Do you know the process of treatment?—It is intermittent downward filtration, and the land is very suitable.

9923. It was one of the first places?—It has about 110,000 population.

9924. You do not know the results they get?—It has been there for thirty years. The land must have been very suitable indeed. The valley is rather wide at that place. I do not remember the exact number of acres at the moment.

THIRTY-FIFTH DAY.

Wednesday, 22nd May, 1901.

PRESENT:

The Right Hon. The EARL OF IDDESLEIGH (*Chairman*), *presiding*.

Major-Gen. CONSTANTINE PHIPPS CAREY, R.E.
Professor WILLIAM RAMSAY, F.R.S.
Mr. THOMAS WILLIAM KILLICK.
Colonel THOMAS WALTER HARDING.

Mr. F. J. WILLIS, *Secretary*.

PRESENT ALSO:

Dr. G. McGOWAN. | Professor R. BOYCE.

Dr. PERCY FARADAY FRANKLAND, F.R.S., Professor of Chemistry in the University of Birmingham, called; and Examined.

9925. (*Chairman.*) You are Professor Percy Faraday Frankland, Professor of Chemistry in the University of Birmingham?—Yes.

9926. You have had a good deal of experience in connection with matters relating to sewage purification?—Yes, for some twenty years past I have studied these matters.

9927. Then can you give us any general statement upon the question?—During the past twenty years I have had much experience in matters relating to the purification of sewage, and have paid attention to the development of the processes employed for this purpose.

In May, 1898, I was requested by the Rivers Committee of the Corporation of Manchester to investigate, in conjunction with Professor Perkin and Mr. Baldwin Latham, the methods of sewage disposal then available, and to advise the Committee as to the most suitable scheme for dealing with the sewage of Manchester.

Our investigation and experiments extended over a period of upwards of two years, and led ultimately to the recommendation of a complete scheme, which, with certain modifications, was approved by the Local Government Board and by the City Council of Manchester. The construction of the works recommended is now in progress. I submit printed reports and diagrams relating to the sewage disposal of Manchester, in which many of my views concerning sewage purification are set forth.

The inadequacy of chemical precipitation methods was fully demonstrated by the experiments of the Rivers Pollution Commissioners of 1868, nor has, in my opinion, anything arisen in the interval to modify their conclusions. It should, however, be pointed out that they under-estimated the purification which can take place in running water under suitable conditions. This purification is now known to be due to bacterial agency in the presence of oxygen or nitrates, and the erroneous conclusions at which they arrived were probably due to the fact that their principal evidence was gleaned from rivers which were so foul that this bacterial oxidising activity had no opportunity of coming into play. The circumstance that the admixture of a precipitation effluent with a very large volume of comparatively pure running water may lead to the rapid oxidation of the organic matter which that effluent contains, shows, of course, that in certain cases mere precipitation may be sufficient to prevent a nuisance. But pursuing this argument further it is obviously possible that in some cases even the admission of raw sewage may be attended with no evil consequences as far as actual nuisance is concerned. *Dr. P. F. Frankland F.R.S.* 22 May 1901.

There is one point of view from which precipitation is of great efficiency, and that is in respect of the removal of micro-organisms. In 1885 I showed that the bacteria suspended in water are removed to a most remarkable extent by the subsidence of solid particles, and if these solid particles take the form of precipitates, as in the case of Clark's process, the removal of bacteria is still more pronounced and may even lead to almost complete sterilisation of the water.

This is a matter which is of obvious importance in connection with the removal of pathogenic bacteria from sewage, and the danger of effluents from a zymotic disease point of view.

The Rivers Pollution Commissioners of 1868 again fully established the very high degree of purification which can be effected by means of broad irrigation and by means of intermittent downward filtration through soil, which was invented by one of them.

Notwithstanding that it is possible by these means (irrigation and intermittent downward filtration) to obtain effluents of a very high degree of organic purity, these methods have on the whole been anything but satisfactory or popular in this country. Amongst the probable reasons for this are the enormous areas of land required (cite Birmingham, where over 2,000 acres are now in the possession of the Corporation for sewage purposes), the unsuitability of many soils, the temptation to apply excessive volumes of sewage to a given

Dr. P. F. Frankland, F.R.S.

23 May 1901.

area, and notably the subordination of purification to the efficient cropping of the land. The frequent practice of sub-letting the sewage farm is, of course, a most potent cause of failure in purification.

Bacteriological research showed that the purification of refuse matter in the soil, whether by irrigation or by intermittent downward filtration, is entirely due to bacterial agency, and with the progress of bacteriological knowledge it was natural that more advantageous conditions for the development of this activity should be arranged. The modern so-called "bacterial methods" are the outcome of such attempts.

Bacteriologists, from Pasteur onwards, have divided bacteria into aërobic and anaërobic forms, and the difference in the mode of life implied by these names is of the utmost importance in connection with the most advantageous utilisation of space in the bacterial purification of sewage. In nature, both aërobic and anaërobic bacteria are found in close juxtaposition, and the chemical changes which they are respectively capable of bringing about go on side by side, the one or the other predominating, according to circumstances. In order to improve upon nature, these forms and the processes dependent on them should be separated as far as possible.

As far as our present information goes the purification of sewage cannot be completed by means of anaërobic bacteria alone, and it is necessary therefore, that in the final stages of the purification aërobic conditions should exclusively prevail.

The supply of sewage to a single bacterial bed, as was done at first, fails to secure such separation of the anaërobic and aërobic conditions, and is a fatal objection to the "single contact" system.

The mere supply of air to a bacterial bed does not insure aërobic conditions, the latter being dependent also on the amount and nature of the organic matter present in the sewage supplied.

The separation of the anaërobic and aërobic processes would be best secured by the application of the sewage to a number of beds placed in series. Such a system may be described as "multiple contact," and the "double contact" beds which my colleagues and I recommended at Manchester were intended to be a practical adaptation of this multiple contact principle. We actually tried "triple contact" for a short period of time with very satisfactory results.

A further separation of anaërobic and aërobic processes is effected by the use of the "septic tank," or "cesspool," in which anaërobic processes can alone take place.

Prior to our experiments at Manchester, there was, I believe, a general impression that septic tanks must be closed to secure anaërobic conditions, but our experience of fermentation phenomena led us to think that no such artificial exclusion of air was really necessary, and in comparative experiments made with open and closed tanks it was conclusively shown that equally good results were obtainable with both.

The covering of septic tanks may frequently be desirable, however, on other grounds, viz., the avoidance of smell, and possibility of gas-collection.

In our first experiments at Manchester we tried the application of crude sewage to the double contact beds, but although a large amount of purification was effected, it led to diminished capacity or blocking of the beds and indicated the great importance of preliminary settlement.

I believe the advantages of such preliminary settlement to be:—

(*a.*) Removal of suspended solids.

(*b.*) Comparative uniformity of sewage reaching beds.

(*c.*) Resolution of a large proportion of the suspended solids and consequent prevention of much sludge.

(*d.*) Resolution of some dissolved organic matters.

The tables appended to our Manchester report show that after putting the open septic tank into operation the results obtained with the double contact beds were uniformly satisfactory.

Many of the failures which have taken place in connection with the use of bacterial beds are doubtless due either to the entire absence of septic preparation or to the application of unduly large quantities of sewage to the beds, also to faulty construction of the beds.

Although, in the first instance, we gave equal periods of contact in the first and second beds of our experimental installation, we always had in view the possibility of modifying not only the number of applications per 24 hours to the beds, but also the possibility of varying the quantities of sewage applied to the upper and lower beds respectively.

Thus, after finding that an effluent of practically uniform excellence could be obtained by the use of double contact, experiments were made to ascertain whether the upper or the lower beds would admit of harder work without prejudicing the character of the final effluent. These experiments showed that the final beds could be treated with a much larger volume of sewage than the upper beds, a result which is of obvious importance, not only with respect to the acreage required for the purification, but also in respect of the manner in which that acreage should be laid out, a larger area of upper than of lower beds being required.

It was further found that the effluent from the upper beds could be most conveniently allowed to flow through the lower beds, thus avoiding the necessity of opening and closing the valves on the lower beds, and thereby saving labour.

At the time our experiments at Manchester were commenced, there was doubt expressed in some quarters as to the possibility of purifying sewage containing trade effluents by the bacterial method. The sewage of Manchester contains a great variety of trade effluents, including those from tar, chemical and dye works, but, notwithstanding, it has proved eminently amenable to bacterial purification.

Manufacturing sewage had, I believe, invariably before been found to yield little or no nitrates on purification, but, by the double contact system nitrification became well established in the final effluent. The production of nitrates is not only of importance as showing the aërobic nature of the purification, but their presence in the effluent serves to prevent putrefaction in the latter.

We have also directed our attention to the grading of the material in the bacterial beds, and are of opinion that the materials generally employed are too coarse. In commencing our experiments we used a coarse upper bed, the clinkers passing a 3 in. sieve, and being rejected by a 1 in. mesh. Being dissatisfied with the performance of this bed, we subsequently altered the grade, using clinker which passed a $\frac{3}{4}$ in. and was rejected by a $\frac{1}{4}$ in. mesh.

We came to the conclusion that the use of comparatively fine material of this kind is of great importance, especially for the first bed, inasmuch as it leads to the arrest of suspended solids in the sewage upon the surface of the bed, from which it can be much more easily removed than if it gains access to the body of the bed, as is the case with coarse material.

The beds employed by us at Manchester retained their capacity in a very satisfactory manner; the permanent capacity being in round numbers about one-third of the tank capacity of the space containing the material.

The double contact beds were not found to be affected by frost, which is a most important feature in their favour, as compared with land treatment. The relative inefficiency of land-treatment during frost was already pointed out by the Rivers Pollution Commissioners.

9928. (*Mr. Killick.*) You advised Manchester on the scheme which they have adopted?—Yes.

9929. You have every confidence in that scheme?—Yes.

9930. It was for septic tank treatment, followed by double contact beds?—Yes, it was septic tank treatment, followed by double contact, which we recommended to the Corporation.

9931. You feel every confidence that that will produce chemically a satisfactory effluent?—Yes, that is my belief.

9932. With regard to the removal of micro-organisms, what opinion have you of the Manchester system?—You mean of the micro-organisms originally present in the sewage?

9933. In the sewage, yes?—Well, I do not think that any very considerable proportion of those micro-organisms will be removed by this process. As far as experiments go with these bacterial beds they show that the effluent still contains a very large number of

bacteria, and, as far as one can see, these bacteria are the same as those which are present in the original sewage to a certain extent, so that I do not think that the bacterial system is calculated to remove the bacteria present in the original sewage with any degree of efficiency.

9934. But an effluent from this system flowing into a stream which is not used for drinking or domestic purposes, do you consider safe?—Oh, certainly. It is quite capable of removing the putrescible organic matter and so preventing any nuisance which might otherwise subsequently arise.

9935. Have you studied the question of the sterilisation of such an effluent at Manchester?—No, we have not attempted to sterilise the effluent there, we do not consider it of any importance at all, because the effluent is discharged into the Manchester Ship Canal, which itself, needless to say, could never by any possibility be used for drinking purposes, so that any sterilisation of the effluent would not only be useless, but probably even prejudicial to the ultimate purification of the effluent in the ship canal, because the bacteria would be better left in it to continue those processes of purification which have already commenced in the contact beds.

9936. In comparing land filtration and artificial filtration, do you think that there is any advantage either in the one or the other?—Both processes are substantially the same in my opinion, only that, of course, in the case of artificial filtration a much larger amount of purifying work can be performed on a given area, but the two processes are identical.

9937. Do you think there is more difficulty in obtaining competent management for one process than the other?—If a sufficiently large area of land is available, and it is really desired to purify the sewage on that land, because, of course, in many cases there is no real desire even to purify the sewage on the land, then I think that it would not require such careful management as the satisfactory management of artificial beds, because if the sewage is distributed over a very large amount of land it cannot get away without these purifying processes coming into play. Of course, it might be so passed through artificial beds that very little purification is really effected unless it was systematically done and properly controlled.

9938. Have you made any comparisons between such a system as Manchester and such a system as that adopted at Chorley?—I am not acquainted with the Chorley Sewage Works.

9939. Chemical precipitation and mechanical filtration?—Mechanical filtration?

9940. Yes?—Of what kind is the mechanical filtration?

9941. Sand filters, polarite and sand?—Well, of course, that has been tried. Continuous filters, I understand.

9942. No, they are not continuous?—Intermittent?

9943. They are practically continuous, yes?—Well of course by continuous filtration through sand you cannot obtain any proper purification at all.

9944. Sand and polarite?—I do not believe that polarite has any value whatever.

9945. Have you any opinion as to the advantage of the septic tank being closed or open before proceeding to put the filtrate upon the contact beds?—Well at Manchester we had a septic tank installation on the lines of the Exeter plant at work and side by side we had an open septic tank of our own arrangement, and there was no practical difference whatsoever between the effluent obtained from these two different kinds of tank. In my opinion there is absolutely no value in closing the septic tank excepting that it may prevent a smell or for reasons of that kind. It may occasionally and frequently be of use to cover it on that account. As far as regards the processes which go on in the septic tank I do not think it makes any difference whether it is closed or open.

9946. Have you considered the question of the duration of the suggested contact beds in Manchester?—You mean——

9947. The life of the bed?—Oh, yes, we went pretty fully into that as far as time permitted and we found that if the beds were properly used they retained practically the same capacity indefinitely as far as we can see. No doubt in the course of a very long time probably diminished capacity and even stoppage might occur, but there was no evidence of that. Of course there were occasions when the capacity of the beds did diminish, but then this arose in connection with experimental work. We purposely overtaxed the beds to see what could be done with them, and on those occasions there was certainly diminished capacity. When we had learned how to use these beds satisfactorily we found that the capacity of the beds practically remained undiminished.

9948. The capacity of the beds immediately decreased, say it decreased to one-third the total capacity about?—About that—yes.

9949. And that you think would remain fairly constant over a considerable period of time?—That was our experience and that was especially the case with the second contact bed. The first contact bed—it is very difficult of course to protect that from the excesses of suspended matter and the suspended matter of course is liable to diminish the capacity of the bed. But on the second contact bed the results were extremely satisfactory as regards the preservation of capacity.

9950. You would say the question as to whether sewage should be treated on land or through artificial filters would depend upon the sewage and the site, in the site I include the accessibility to land and the cost of the land?—Yes, I think the cost is the principal factor which would determine in the choice between land and artificial beds. Of course the construction of these beds is costly, I believe it is often unnecessarily costly, but I suppose there can be little doubt that if land can be obtained at a sufficiently low price it would be possible to purify the sewage at a smaller expense on the land than by means of artificial beds.

9951. (*Colonel Harding.*) You said that in nature the aërobic and the anaërobic actions go on in juxtaposition and that it is desirable in trying to improve on nature to separate them as far as possible?—Yes, I think so.

9952. And you think therefore that by scientific dealing with the question of sewage treatment on artificial beds it is possible to obtain more perfect results than by land or as perfect results upon very much smaller areas?—On a much smaller area—yes.

9953. And artificial filters would be more under control, would they not, than land, under more ready supervision than land areas because of their smaller area?—Yes, certainly you could have them under more immediate supervision than large areas of land.

9954. But your suggestion that in connection with land there is a temptation to exaggerate the volume which is being dealt with on a given area, surely does not apply to land treatment only; it applies equally to artificial filtration, does it not?—Oh, of course there might be the same temptation on beds.

9955. Exactly the same?—Well, not exactly the same, because in the case of land it is so frequently the case that they wish to derive a profit from crops on the land. Now there is no temptation of that kind.

9956. But in so far as they want to have crops they will not exaggerate the volume they are dealing with on the land but rather the other way will they not? That is another point. They would rather deal with less sewage and let it flow. The temptation in that case is to let it flow direct to the stream untreated rather than to put too much on the land?—Well of course that is what one frequently sees at sewage works.

9957. The temptation of overdoing the dose upon a given area applies equally to the artificial filter as to land; it is not an argument against land?—Yes, I think it is, because even supposing you have acquired a large sewage farm and if they are attempting to work this sewage farm to get a certain return from it they will only put as much sewage on to the land as will suit their crops and the rest of the sewage they will short-circuit so to speak, pass it over some land, but quite an insufficient quantity, and let it go straight into the stream, and I have seen that happening constantly.

9958. And you consider it an advantage of artificial filtration that, having nothing to do with crops, that kind of temptation does not arise?—Yes, I think that is a great advantage.

9959. Now you say that where sewage is being dealt with entirely upon contact beds it does not necessarily

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follow that on an aërated bed the action is aërobic?—No, it does not depend simply on the supply of air, it depends also on the amount of organic matter which is present in the sewage applied.

9960. Well you experimented in Manchester with crude sewage upon contact beds?—We did at one time—yes.

9961. And you came to the conclusion, which others have come to, that it is impracticable to deal with crude sewage on contact beds because of the large quantity of suspended solids?—Yes, we found that our first contact bed was blocking.

9962. But upon the point whether the action was aërobic or anaërobic upon that first contact bed have you formed an opinion?—Yes, I should think it was probably both, partly aërobic and in part anaërobic, but largely anaërobic, and certainly the oxidation was by no means complete. There were no nitrates for instance or barely any in the effluent from the first contact bed, so that I do not think there could have been properly established aërobic action going on in that bed, otherwise we should have had nitrates in the effluent from it.

9963. And the conclusion you came to at Manchester was that it was desirable before dealing with sewage on contact beds to have an antecedent treatment?—Oh, certainly.

9964. Now as to the relative value of a septic treatment as an antecedent treatment and chemical precipitation, you say you do not know anything about the Chorley Sewage Works, but at Chorley they have a very perfect system of quiescent settlement and they produce an effluent which is very free from suspended solids. You are of opinion, are you not, that an effluent of that kind would be admirably dealt with on contact beds?—Oh, yes, certainly in fact we had experiments of that kind going on at Manchester. The whole of the Manchester sewage is treated chemically with lime and proto-sulphate of iron and the effluent from the tanks in which it is so treated has been for years allowed to pass on to certain beds which were put down there by Sir Henry Roscoe about six years ago, and the effluents from those beds have always been very satisfactory.

9965. And have you formed any opinion as to whether it is better to deal with a septic effluent or an effluent from good chemical precipitation in order to bring about good results in the final filtrate?—Well, I cannot say that I have instituted any very strictly comparative experiments of that kind, but the effluent from our contact beds—it is true they were double contact beds whilst the beds which dealt with the chemical effluent were only single contact beds—our double contact beds effluent was much superior to the effluent obtained from the single beds which had had chemical treatment before.

9966. That, of course, you would expect, and that would be due to the double contact?—Yes, it may be due to that, or it may be due to the septic treatment.

9967. That is the point now I am coming to. Do you think that the chemical precipitation would bring about antiseptic conditions which would vitiate the action of the filters afterwards?—Oh, no; if the amount of chemicals is that which is usually applied I do not think they would have any appreciable antiseptic action at all.

9968. You think not?—No.

9969. Then do you think that the septic tank anaërobic treatment is of value in preparing organic matter for the aërobic action in the contact beds?—Well, I do not think that any very decisive experiments have been made on that subject; it is more inference and *à priori* reasoning than anything else as far as I know.

9970. There is an interesting suggestion in your evidence as to the settlement of suspended matter affecting the quantity of bacteria in an effluent, and I think you tell us you have formed an opinion that in completely settling the suspended matter you remove in large part the bacteria from the effluent?—Yes, that is so, by chemical precipitation if it is properly carried out a very large proportion of the bacteria can be removed; in fact, for instance, in Clark's softening process the water is almost sterilised by the treatment, not sterilised through the lime acting antiseptically, but through the subsidence of the bacteria along with the suspended carbonate of lime which goes to the bottom.

9971. Then you would advise us as a Commission to insist that all effluents going into a stream should be as free as possible from all suspended matter, although such suspended matter might be non-putrescible?—Oh, I think certainly if it has to go into a stream which is afterwards used for drinking purposes it would be of great advantage to have the maximum removal of bacteria originally present in the sewage.

9972. In other cases, of course in a stream not used for drinking purposes it is of no consequence?—It is of subordinate importance.

9973. Have you formed any opinion from the experiments at Manchester, which, I take it, you are still watching, as to the amount of the consumption of suspended solids which takes place in the septic tank?—No, I have no direct experiments on that point, more than the mere qualitative result that the amount of sludge accumulating in the septic tank was very small indeed.

9974. We have information from Mr. Fowler on that point, and as you have no personal knowledge upon it I will not press it?—Yes.

9975. As a chemist, can you give us any opinion in regard to the question of nuisance arising from septic tanks? From your own experience at Manchester you have gathered no doubt that there is no appreciable nuisance from the open septic tanks at Manchester, have you not?—Yes, that is my opinion, that the amount of nuisance was very trifling. There is a smell; you cannot have these large tanks without some smell arising from them, but I cannot say that it was very disagreeable.

9976. Then the gases produced are all inodorous, are they not, at Manchester?—Well, not altogether inodorous. The principal gas, of course, is marsh gas, which is inodorous.

9977. Carbonic acid, hydrogen, nitrogen?—There are other products which are odorous.

9978. But are they not in solution, those products?—Some of them will be carried off with the gas.

9979. The evil smelling products are in solution, are they not?—Well, I should not like to say that definitely. I think some of them are gases, or at any rate capable of passing off as vapours.

9980. Have you ascertained whether the nuisance is connected with the stirring up of the septic effluent or whether it is due to the emanations from the septic tank?—The septic tank itself certainly has a smell, there cannot be any doubt about that, because the septic tank which we used at Manchester was very much larger than the beds; I mean was very much larger in proportion than the beds on which we purified it so that if you stood near the septic tank you were practically getting the smell only from the septic tank not from the effluent which was passing from it on to the contact beds.

9981. Have you any experience of your own upon the question of nuisance arising from the septic tanks where they are used for domestic sewage pure and simple?—Well, I had a cesspool myself in connection with my house, and of course, from the cesspool itself there was no smell which could get out into the open air as it was covered up, but when the sewage was pumped from this tank there certainly was a smell whilst it was being pumped; it did not last very long.

9982. I should think it is a bad smell in that case?—Oh, it would be very disagreeable to most people; in fact, the neighbourhood objected, the immediate neighbours objected to this smell, and ultimately the houses were connected with the main drainage, but it is not a very disagreeable smell in my opinion.

9983. Do you not think the presence in Manchester sewage of iron compounds would tend to minimise the nuisance?—Oh, I do not think the amount of iron in the Manchester sewage is sufficient for that.

9984. Would they not take up the sulphur?—No doubt they would, but the amount of iron in the Manchester sewage is not generally very large. Occasionally considerable quantities of iron "pickle" liquor come down, but the Manchester sewage is not characterised by containing a very large amount of iron.

9985. Now as to your contact bed experience at Manchester, you have come to the conclusion there, the same as Mr. Fowler, that it is desirable to use graded

material in such a way that the finest material is at the top of the first bed?—Yes, that is my opinion.

9986. With the object of getting as far as possible the suspended matter on the surface?—Yes.

9987. Of course it is most interesting to us to know whether using beds so constructed it is possible to maintain their capacity for long periods; do you not think there would be danger not only of this suspended matter on the surface, but of that fine material itself gradually making its way down into the interstices of the coarse material below, and so bringing about the reduction of capacity by consolidation?—Well, we did not find that to be the case. As matter of fact, the fine material remained on the top and it could be just forked over and the permeability of the bed was at once restored.

9988. You think in practice that danger would scarcely arise?—I do not think so.

9989. In Manchester it is fair to say is it not, that your experiments are on a very small scale?—Well, the beds were not very large, but they were sufficiently large I think to draw conclusions from.

9990. Well, they have now at Manchester a half-acre bed at work, have they not?—I believe so.

9991. Have you any personal experience of its working?—No; I have no personal experience of its working.

9992. It is no use my asking you whether the results they have found on that larger bed harmonise with those which were found on the smaller?—No, I cannot give you any information.

9993. You have not personally gone into the question of the cost of these beds?—No, I have not.

9994. But you recognise that artificial filtration must necessarily be very costly?—Well, I have seen beds for instance at Oldham which I understand cost £100 per acre. They are simply dug out of the ground and the sides are protected with boards, and I was given to understand that these beds worked very satisfactorily.

9995. But what was the material used?—Oh! clinkers were put into the beds, a porous material.

9996. Possibly the £100 an acre might be, in that case it would surely be, a very small estimate, the cost simply of excavating the hole into which to put the material?—No; I understood the bed as completed cost £100 an acre.

9997. I would advise you to inquire into that; it would be a most delightful solution of the matter—

9998. (*Major General Carey.*) The cost of the material on the spot?—But the cost of the material in any case would be insignificant compared with the cost of the beds. I should mention that the contents of those beds were not graded in any way. There is a great expense in connection with the grading of the material.

9999. (*Colonel Harding.*) No doubt that is a serious source of expense. You have not any experience of your own, have you, upon continuous filtration?—No, I have not.

10000. Trickling filtration, aerobic filtration?—Yes, I have seen it going on, for instance, at Accrington, and I had the effluents from it analysed, and it was very satisfactory, but I have not the same kind of experience of that as I have of these contact beds.

10001. (*Prof. Ramsay.*) We were told yesterday by Dr. Klein that pathological bacteria are destroyed by simple length of time in contact beds with other bacteria, and he led us to believe that sewage treatment on arable land gave them a longer time to be exposed to other influences, and therefore killed them out. Have you any experience of the same sort in connection with bacterial work?—Well, of course, I have made a great number of experiments on the longevity of pathogenic bacteria in water, and that is the result at which I arrived that if you put pathogenic bacteria into unsterile water, these pathogenic bacteria disappear within days or weeks as the case may be, but I have not made any experiments of that kind on land, but I can easily conceive that that would be the result of prolonged rest on land, and contact with other bacteria would lead to their destruction.

10002. That might be an argument in favour of land treatment?—Oh, I think it might; yes.

10003. I wish to ask you, have you had much experience of sewage treatment on farms?—Well, I have never had anything to do with the management of such farms, but I have been on these farms and seen the way in which the sewage is there disposed of—for instance, at Birmingham and other places.

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10004. Have you ever seen a well-managed sewage farm in which the effluents were really constantly running out clear, and giving good results on analysis?—Well, I have analysed the effluent from the Croydon farm within the last few years, and I may say that it was not as satisfactory as the effluent from our contact beds, and I have seen certain cases where the effluent was practically not purified at all after running off the most magnificent land.

10005. But put it the other way round. Have you ever seen any effluent from land that was continuously good?—Well, I cannot say that I have ever watched a sewage farm in that minute way to be able to answer that question satisfactorily.

10006. That point in your evidence as regards the removal of bacteria by chemical precipitation, by the formation of precipitate, strikes me also as very interesting. Has it ever occurred to you that an effluent after treatment by bacterial process could be sterilised by chemical precipitation?—Oh, it could certainly be done, you mean to put the precipitation plant after the contact beds?

10007. After the contact beds?—Yes, that could certainly be done.

10008. Would that greatly reduce the number of bacteria?—Of course, it would have to have sufficient length of time for subsidence.

10009. Naturally?—And the subsidence you would have to give it would be considerably more prolonged than is usually possible in sewage works under existing circumstances.

10010. Would it be possible to remove the suspended matter by ordinary filtration, for instance, through sand and some bed of that kind, after treatment?—Oh, I do not see the slightest objection to that. Of course, we know that in the filtration of water through ordinary water works filters the bacteria are almost entirely removed if the process is properly carried out.

10011. Perhaps I had better begin a little further back; do you consider the water of Oxford and of Reading and of Henley should run into the Thames, which is used for drinking purposes?—I think that the unfiltered Thames water is unsuitable for drinking purposes; yes.

10012. But after filtration the sewage which goes in higher up produces no bad effect?—There is not the slightest evidence that it produces any ill effect among the consumers in London.

10013. And you think it would be unnecessary for the Oxford and the Henley populations to sterilise their effluents?—As far as experience goes it would appear to be quite unnecessary; I mean, of course, theoretically, we can see that there may be a loophole for danger, but there is no evidence that any evil result has accrued from the use of filtered Thames water.

10014. Have you any experience as regards the distance down a river which bacteria can pass and still survive?—Well, some years ago I made a number of experiments on the river Dee, above Aberdeen, where there are a number of small sources of pollution along the Dee from various villages; where these pollutions entered the number of bacteria was very considerably increased, but as one proceeded down the stream the numbers again diminished. I could give you in fact the exact figures for that if it were not taking up your time.

"Above Braemar the Dee was found to yield only eighty-eight micro-organisms in 1 c.c., and is, therefore, bacteriologically of great purity. The next sample was taken from the river below Old Mar Castle, and after thorough incorporation of the tributary Cluny (which receives the sewage of Braemar). This accession is marked by a large increase in the number of microbes, there being found as many as 2,829 in a c.c. Another sample was taken above the Bridge of Ballater, and it shows that the number of micro-organisms has been reduced by rather more than one-half in the flow from Old Mar Castle to this point, for only 1,139 were found in the c.c. A sample examined from the Dee 100 yards below the Ballater Sewage Pond outfall, on the other hand, shows a large increase, in the number of micro-organisms, as many as 3,780 being obtained from a c.c. The cause of this increase, notwithstanding the very small quantity of liquid coming from the

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pond at the time (10 o'clock in the morning), is not far to seek; for as many as 235,000, 273,000, and 26,000,000 were found in the effluent from the sewage pond and, the sewage outfall channel above the pond at Ballater respectively. On following the Dee down, a sample was taken above the junction of the Neil Burn, Kincardine o' Neil, and it was found that the micro-organisms had again fallen to about the same number as above Ballater, the number amounting to 938 in the c.c. Below the entrance of the Neil Burn, which at the time of the investigation was a mere dribble, the number of micro-organisms had again perceptibly risen, 1,860 being found in the c.c. The Neil Burn itself, twelve yards below sewage outfall, was found to be very rich in micro-organisms, as many as 1,200,000 being obtained in the c.c. The river on reaching Invercannie, however, again exhibits just about the same number of micro-organisms as above Kincardine o'Neil, or above Ballater, only 950 being found in the c.c. The total number of miles of the river's flow which was covered by the examination was upwards of 40."

10015. So that there is a very considerable amount of purification?—Oh, I believe so, and in this case I should mention that it was impossible by chemical analysis to even ascertain any contamination of the river at all. It was only shown in the bacteriological examination. The river is very pure from a chemical point of view, but these small pollutions very materially affected the bacteriological character.

10016. It is a very important question for this Commission to make up their minds whether any recommendation should be made as regards sterilising effluents which enter a drinking stream. I put this case as an extreme one:—Supposing an epidemic of typhoid fever were to break out at Henley or at Oxford, would that seriously imperil the population of London in your opinion?—There is no experience that any such thing has resulted. I mean typhoid fever, of course, is always prevalent in the upper Thames Valley, and yet nobody has ever been able to show that any typhoid fever in London was connected with these epidemics of typhoid fever above, although many people have tried to show it, and trace such a connection, but it has never been successfully accomplished.

10017. Then it is your opinion that sterilisation of effluents which enter a drinking river which is afterwards to be filtered may be neglected. It need not be sterilised?—Well, I think that is the practical conclusion one comes to, though, of course, theoretically one would like to see them sterilised, no doubt.

10018. It would be advisable to sterilise them if it could be done cheaply?—Oh, yes, I quite agree to that.

10019. Have you given any consideration to the sterilisation of effluents?—No, I cannot say that I have.

10020. What do the water companies do with the wash waters which contain the bacteria filtered out from the water?—That passes into the river at the waterworks. This is, of course, below the point of intake.

10021. Have you had any experience of the utilisation of sludge? Do they utilise the Manchester sludge?—No, it is simply dug into the ground there, it is used for filling up the old river bed.*

10022. There is a process suggested at Chorley for dry distilling the sludge, and producing a kind of gas. Have you ever heard of that?—No, I have not.

10023. You make a statement that bacteriological research showed that the purification of refuse matter in the soil, whether by organic or by intermittent downward filtration, is entirely due to bacterial agency. Is that statement to be taken without reserve? Is there no oxidation otherwise than what occurs through the medium of bacteria?—Well, I think that it has been shown that if the bacteria are destroyed in any way these changes cease.

10024. Have you made any special experiments?—No. I have not myself, but the researches of Pasteur and of Schloessing and Muntz show that, and, of course, incidentally, I suppose every bacteriologist has evidence of that, inasmuch as his culture materials and so on retain their composition for an indefinite period of time as long as they are sterile.

10025. What was supposed to be the action of a continuous filter—anaerobic or aerobic?—I should imagine that at the top of the bed to a certain extent it would be anaërobic, and that you would get more and more aërobic processes as you passed to the bottom, and I should think that is the case also with land; where there is any considerable amount of organic matter you would be obliged to have anaërobic action.

10026. To begin with?—Yes.

10027. Have you any data of your own on the amount of suspended solids or of dissolved organic solids which are dissolved in a septic tank?—No, I do not think so, but that seems to me a very difficult matter to determine at all, because the composition of the sewage you see entering the septic tank is varying from minute to minute, and it is almost impossible to know what the amount of suspended matter entering has been.

10028. You have not thought of any device by which it would be possible to determine how much of the suspended or dissolved organic compounds are decomposed in the septic tank?—Dissolved?

10029. Dissolved or suspended organic matter?—No, I do not see how it could be done with any degree of accuracy. Of course, by multiplying the number of samples of entering sewage and of the leaving effluent from the tanks an idea might be arrived at, but I think it would not be of a satisfactory character.

10030. Have you examined septic tank liquor for pathogenic bacteria?—No, I have not.

10031. Have you any idea as to whether they would form breeding grounds for pathogenic bacteria, or whether they would kill them out?—Well, as far as one can judge, of course, the competition of the large number of non-pathogenic organisms—septic organisms, and so on—would be detrimental to the pathogenic bacteria which were present, but I do not think the evidence is very decisive on that point. Of course, it is a matter of great difficulty to detect pathogenic bacteria in a liquid which contains such a large number of other bacteria.

10032. That is quite true. Passing on to the nitrifying bacteria, the nitrite and the nitrate, have you any special experiments of those to determine which is the lowest temperature at which they act?—No, I have not any direct experiments on that. Of course, we know that the higher the temperature the more rapidly——

10033. Yes, we do; does their action cease with frost?—Well, it never ceased in our beds; but there is evidence as to that in the case of the Rivers Pollution Commission. They found that the effluent from these farms at Croydon and Norwood contained considerably less nitrates during the frosty weather than during the ordinary summer weather, or even spring and autumn. During frosty weather the amount of nitrates was very considerably reduced. This is referred to in their reports in the year 1870 or thereabout. Would you like to have the reference to it?

10033. I think we know generally the statement that it is so. I did not know whether you had any special experiments?—No; but I might mention in that connection that I think that is one of the advantages of the contact beds, that, of course, the temperature of the liquid in these beds is practically independent of the outside temperature, whereas in the case of land, it is entirely conditioned by the outside temperature. It is distributed in such a very thin layer over such a large area of land, the liquid is much more affected by the air. Now, in winter the temperature of sewage is proportionately higher than in summer even.

10035. Have you examined the surface of soils, the ground below the surface of soils, for nitrate or for evidence of nitrification? Have you examined the soils somewhat below the surface for evidence of nitrification or for nitrate bacteria?—No, the nitrate bacteria which I cultivated were taken from the surface of the soil.

10036. Are they more numerous on the surface than further down?—Mr. Warrington, you may remember, made very extended experiments on that subject, and he found them, I forget now to what depth, I think it was 6 ft. or 12 ft. He published two series of results In the first set he said they did not extend beyond 18 in. or 3 ft., or something of that kind, and then he tried another method of cultivation, using sulphate of lime, by which the nitrifying bacteria are apparently very much stimulated, with the result that he found them to a very considerably greater depth when he used that method of cultivation; but I think there can be no doubt that nitrification goes on to a considerable depth in the soil.

* For some years past the Manchester sludge has been taken out to sea by a sludge steamer in the same way as at Barking and Crossness.

10037. And in a peaty soil do you know what takes place pretty well?—Oh, I think in peaty soil nitrification very rarely takes place. Nearly all the waters which are derived from peaty areas are practically free from nitrates altogether.

10038. But containing nitrogen in other forms of combination?—Oh, yes, both ammonia and organic nitrogen. Of course, for one thing the acidity of the water prohibits nitrification. Nitrifying bacteria are very sensitive to acid.

10039. Have you had any experience of sulphuretted hydrogen bacteria?—No, I have not.

10040. In the chemical analysis of effluents what item do you regard as the most important—for instance, albuminoid ammonia or oxygen absorbed?—Well, I think that both the albuminoid ammonia and the oxygen absorbed ought to be taken into consideration and in a more limited number of samples, of course, the organic carbon and nitrogen.

10041. The total organic carbon and nitrogen?—The total organic carbon and nitrogen, yes.

10042. Do you return to them after aeration of the effluent?—No, we do not do that. In the Manchester experiments they were all also submitted to the incubator test.

10043. You think that test is of value?—Yes, it appears to me to be of great value.

10044. Is there any simpler test which you could put into the hands of a workman to give a general idea of the working of bacterial beds?—We considered that very carefully at Manchester, and we came to the conclusion that perhaps the best test which could be employed was the oxygen absorbed in three minutes as giving an indication—a very rapid indication—of what the amount of organic matter was. We found that such determinations agreed fairly well with those obtained when a longer duration was given to the action of permanganate.

10045. And with an uniform sewage it would give correct comparative results, do you mean?—Oh, I think it would give a very good idea of what was going on, and if the sewage was stronger the workman would know that he had to treat it more carefully than if weaker.

10046. Have you had any experience except at Manchester of manufacturing refuse?—Not in the same way. Of course, I have been at sewage works where there was manufacturing refuse, but I have not had it under observation in the same manner.

10047. Have you formed any opinion as to what should be done with it—whether it ought to be allowed to enter the sewers or dealt with otherwise?—Well, I think certain forms of manufacturing refuse would be best kept out of the sewers altogether, but if that is impracticable I think the manufacturer ought at any rate to be compelled to discharge his refuse uniformly over the 24 hours instead of letting it off in sudden rushes as they very often do. I have generally investigated these manufacturing refuses from the following point of view. If it is asked whether particular refuse is likely to interfere with the treatment of the sewage I have mixed this manufacturing refuse with water and determined whether the number of bacteria multiplied or diminished in such a mixture, and if the bacteria multiplied largely I took it that the manufacturing refuse could not interfere much with any bacterial processes.

10048. Have you got any view on the question of standard for sewage effluents?—Well, in the case of Manchester we worked to the standard which is prescribed by the Irwell and Mersey Joint Committee, which, as you doubtless know, is one grain of oxygen absorbed per gallon and ·1 of albuminoid ammonia. This seemed to be a very reasonable standard, and the effluent complying with this standard generally also stood the incubator test, which I think is the best test to apply if you are wishing to avoid a nuisance in the stream into which you discharge the effluent.

10049. Have you got any general views in regard to the desirability of having a standard?—Well, I think the stream into which the effluent is discharged must be a standard itself. I do not think it ought to be permitted that an effluent of worse quality than the stream itself should be discharged, excepting when the stream is exceptionally so good that you could not quite comply with such a standard, but I mean it would be absurd, I think, to require a very high standard in the case of an already considerably polluted stream.

10050. But unless one makes a standard and sticks to it the chances are that those polluted streams will never improve?—Well, of course, there is that to be said for it.

10051. You would consider that as a reasonable standard for the present?—It seemed to me a very reasonable one. It was adopted as being similar to the one laid down by the Rivers Pollutions Commissioners, which was, as far as I remember, two parts of organic carbon and 0·3 part of organic nitrogen per 100,000 in solution.

10052. Yes, it was?—Which has always been considered a very severe standard.

10053. Then upon non-potable rivers which are not going to be drunk would you take that as the same standard? You think that applies to a stream which, at all events, will not be any nuisance?—I believe that if that standard is maintained no nuisance would arise.

10054. Have you a standard for drinking water?—Do you mean for the composition of drinking water?

10055. For the composition of drinking water is there a standard?—Oh, no; I think one must take into consideration the nature of the water. For instance, we might have an amount of organic matter in peaty water which would be quite inadmissible in the case of well water. The quality of the organic matter is the determining feature.

10056. Have you studied cellulose fermentation?—No, I have not.

10057. (*Major-General Carey.*) With regard to the effluent from the Croydon farm, which I think you say that you have analysed?—Yes.

10058. Was the analysis made before the sewage was passed through a coarse bacteria bed, or was the effluent taken straight from the land?—I understood it was coming straight from the land at that time.

10059. How long ago was it?—Oh, it was in 1898, I think. I did not understand that there were any beds at that time.

10060. At Norwood and Beddington they have now assisted the land by passing the sewage through coarse beds, but that was on account of the increased volume of sewage due to the increased population. Would not the same necessity exist in bacteria beds as the population increased, assuming that the bacteria beds are designed for a certain population, and in a few years that population materially increases? There would be a constant liability of bacteria beds being overtaxed by the volume of sewage put on them?—The beds would undoubtedly have to be increased in area as the flow of sewage increased also.

10061. Depending on the goodwill or the judgment of the authority? We find it very difficult indeed to induce an authority to increase their area of land after they have once started?—Yes, of course.

10062. That would be a cause of failure which would be common to both systems of treatment?—Yes, certainly.

10063. And there might also be another liability to failure due to the difficulty of procuring suitable material for the filters?—Well, it has been shown that this clinker is a very efficient material, and there does not seem to be any likelihood of the amount of that which is available being limited.

10064. There would be no difficulty in geting it in any part of the country?—Of course the price will vary considerably in different parts of the country.

10065. I understood the price had gone up owing to the demand at Manchester?—Oh! they try to make local rings to rush up the price.

10066. In Wales they suggested slate as the only medium they had?—Well, there is a great variety of material.

10067. Those are all experimental to a great extent except clinker and coke. Slate and other material are experimental?—Well, in every place there is some local material which may be used. For instance my attention was called the other day at Burslem to a material which they employ with great success. It is the "saggers" from the potteries. It is a magnificent material for sewage filters; it is very porous, very hard, and I should think it is superior to clinkers, and an unlimited quantity of it is available. I think with a little ingenuity probably in any place a local material can be adapted to the purpose.

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10068. Then the possible renewal of the filtering material would have to be taken into consideration during, say, a period of ten years?—It will have to be taken into consideration.

10069. In estimating the cost of bacterial treatment versus the treatment by broad irrigation on land?—Yes, the cost of that must be taken into consideration and the possibility of having to incur that cost should act as a deterrent in over-working the beds, and should lead to the beds being used carefully, because the more carefully they are used the longer no doubt their capacity will be retained.

10070. If suitable land can be obtained at a reasonable price would you recommend its adoption in preference to bacterial treatment say in rural districts where the supervision is not perhaps very good?—I think for the contact beds it is essential to have proper supervision.

10071. Yes; I am now assuming that you could get land, sufficient land and suitable land at a reasonable cost?—Yes.

10072. A small village has to choose which treatment it will adopt, whether it will take an acre or two acres of suitable land, or whether it will adopt bacterial treatment; have you any opinion as to which course they should take?—Well, I think that the land would require less skilled supervision than the bacterial beds. I think that would be an important determining factor in the choice.

10073. With equal efficiency in purification if it is well managed?—I think that from the land with less skilled supervision you could get as good (or better) an effluent as from the beds.

10074. Depending on good management in both cases?—You cannot get out of the management in either case. I do not think it requires such a skilled man to work land satisfactorily as it would to work beds satisfactorily.

10075. Are the chemical changes which take place in the purification of sewage on land precisely the same as those by the bacterial process?—Yes, I take it that they are exactly the same because the effluent is chemically at any rate undistinguishable in the two cases.

10076. The purification is merely at a slower rate?—You mean in the case of land?

10077. In the case of land?—Yes.

10078. That is all the difference?—Yes, I imagine that to be the only difference.

10079. Have you made any experiments or do you know whether a septic tank effluent could be treated directly on land, without injury to the land or without creating a nuisance?—I have heard that it can be. I have not any experience of it myself.

10080. Not any practical experience?—No; but I know that at Birmingham they are treating it on land with great success.

10081. From the septic tank?—From the septic tank—yes.

10082. And is part of that land laid out as pasture?—It is laid out in various ways, partly as intermittent filters and the greater part of course is broad irrigation at Birmingham. But they are using septic tank effluent very much now and they are very well satisfied with it.

10083. No injury is done to the grass?—No.

10084. And no nuisance is created?—No, I have not heard of any.

10085. You say: "It was further found that the effluent from the upper beds could be most conveniently allowed to flow through the lower beds, thus avoiding the necessity of opening and closing the valves on the lower beds, and thereby saving labour." Is the effluent from the upper beds passed continuously through the lower beds?—Oh, no; you mean in that case?

10086. Yes, at Manchester?—No, you see contact was given for two hours, or whatever it might be, on the upper beds, and then the valve was opened, and it was allowed to flow out on to the lower bed in the ordinary way, but the valve of the lower bed being partially open permitted the liquid to flow continuously through, so that the time occupied in passing through the lower bed was the same as if the valve had been first closed and then fully opened in the ordinary way. Supposing the contact was to be two hours, the valve of the lower bed would be so opened as to permit the effluent from the upper bed to stream through the lower bed in two hours. This method was occasionally employed.

10087. In a continuous stream?—In a continuous stream, yes. There was no curtailing of the contact; it was only that it was allowed to continuously run through instead of being bottled up for a certain length of time; in fact, we found in Manchester that the necessity for contact in the case of the second bed was very much less than in the case of the first, so that it would probably be more desirable to have a larger number of upper beds than lower beds; in fact, when we passed the effluent from the upper beds through the lower beds at twice the rate, we found that we were still getting an excellent effluent.

10088. And you have had no difficulty in treating and purifying the sewage mixed with manufacturing refuse?—No, there has been no difficulty with that in Manchester at all, and of course the sewage of Manchester contains effluents from dye-works and from tar-works, and a great variety of works of that kind.

10089. Do you consider that crude sewage should be treated on contact beds without previous sedimentation?—It seems to me highly undesirable that it should be done, because it must lead to the blocking up of the beds.

10090. (*Chairman.*) Did I understand you correctly, and do you think that sewage can be purified just as well by artificial means as it can by land treatment?—Yes, that is my opinion.

10091. Then it really comes in the end to a question of cost?—Yes, I believe that to be the case.

10092. Have you calculated at all in connection with the prevention of sludge? What the proportion of prevention comes to?—With the septic tank?

10093. Yes?—No; I could not give you any exact figures on that subject.

10094. Then may I ask you to give us your definition of the difference between broad irrigation and intermittent downward filtration?—Well, I suppose that one really passes imperceptibly into the other, but in the case of intermittent downward filtration the process of giving the land rest is carried on in a more systematic manner. The sewage is put so many hours on to the particular plot of land, and that particular plot of land is then left at rest for a definite period of time; and the underdraining, I take it, of the land in question, must be much more carefully carried out than in the case of broad irrigation.

10095. But there is no distinction in principle between them?—No; I think none whatever.

10096. (*Professor Ramsay.*) There is one other question arising out of one of your answers. You said that certain trade effluents should not be allowed to go into the sewers; can you specify what?—Well, such things, for instance, as coal-tar, and anything which is practically indestructible.

10097. Or antiseptic?—And antiseptic.

10098. For instance, iron "pickle"?—Well, I do not think it would be quite fair to prohibit a substance simply because it was antiseptic, because if specially diluted it might not have any antiseptic action at all. That is the case with "pickle," sufficiently diluted, mixed with otherwise alkaline sewage, it probably would not do any harm at all, and possibly may do good.

10099. What about equally poisonous substances such as lead compounds and matters of that kind; do you think restrictive measures should be taken as regards those?—Well, I think on theoretical grounds, certainly. I do not know if it could be rigorously enforced.

10100. (*Professor Boyce.*) I gather from your Dee observations that you lay considerable stress upon the bacteriological test?—Yes, I do.

10101. That in that particular case you could not have discovered sewage pollution without it?—No, the chemical analysis of the water did not indicate any sewage pollution at all.

10102. You would therefore favour a bacteriological test in those cases where effluents went into drinking streams?—Yes, certainly.

10103. Would you take the bacillus coli as evidence

of sewage pollution or surface pollution?—Contact with the surface of the land, I should say, but I do not think it can be regarded as proof of sewage contamination.

10104. Why do you not think it can be regarded as proof of sewage contamination?—Because I do not think it has been shown that water which comes from any ordinary soil is free from the bacillus coli.

10105. Have you yourself examined moorland streams to ascertain whether moorland streams are free from the bacillus coli?—I have found them. The refuse of other animals contains bacillus coli.

10106. Yes, but practically speaking, would you say that moorland streams contain the bacillus coli?—Yes; I have found them in such streams.

10107. Would you take them as evidence of sewage pollution?—Well, I do not know that there is any specific test of a bacteriological character. Of course, if the water does not contain bacillus coli, so much the better; but if it does, I do not think you can say definitely it has been polluted with sewage.

10108. For instance, if you found a small number of bacillus coli and a large number of bacillus coli, would you not think the finding a large number of bacillus coli was presumptive evidence of sewage pollution?—I should be more inclined to look with suspicion on the water, of course, the larger the number of bacillus coli.

10109. Then you would not rely on a bacteriological test as evidence alone of sewage pollution?—No; I think that the bacteriological and chemical should be taken in conjunction with the surroundings, and the source should be carefully considered also.

10110. In the case of effluents going into a stream that is likely to be drunk, would you be inclined to lay down a rigorous standard—bacteriological standard—for the purity of the effluent, or would you make it dependent upon the size of the stream and other circumstances?—Well, I think that theoretically, of course, we should like to see the effluent sterilised or deprived of any possibility of containing sewage bacteria. If there are any sewage bacteria left there may be pathogenic bacteria with them, but I do not think that experience shows that this is really of very great importance, because there is no evidence that properly filtered drinking water is capable of communicating zymotic disease.

10111. Returning to those Dee experiments, did you examine the mud of the banks of the Dee and the river at all?—No, only the water itself.

10112. You would, I suppose, expect a large increase of bacteria in the mud and in the bed of the river?—If polluted.

10113. In case of pollution?—Oh, yes, certainly.

10114. Do you think that that constitutes an increasing element of danger?—No, I am not prepared to say that it does, because I think that in this mud there would be a competition between pathogenic and non-pathogenic bacteria, probably to the detriment of the pathogenic.

10115. You have not perhaps yourself made observations on that point?—Not in mud. Of course, I have in the case of putting pathogenic organisms into ordinary drinking water.

10116. I am aware of those experiments, but you would not be surprised to find, in the case of the river Dee just below the source of pollution, that the mud contained a larger proportion of bacillus coli than the water?—Yes, that might be so.

10117. There might, would it not, be evidence of accumulation of bacillus coli?—Yes, it would.

10118. Now, in the case of Manchester you said that practically speaking it did not matter whether the bacillus coli, and I take it pathogenic organisms, got into the effluent and passed into the Manchester Ship Canal?—No, I do not think it of much importance.

10119. Well, what do you think would take place in the sludge? Do you think that if you examined the sludge there would be a large increase of bacillus coli in the sludge just like in the case of the Dee?—I think that they would accumulate in the sludge to begin with, but they would probably be destroyed in the sludge through the competition with the anaërobic septic bacteria which were there also and flourishing abundantly in that medium.

10120. Yes, but just as in the case of the Dee if you made an examination now and took some of that sludge, you would not be surprised to find that the sludge contained a larger number of the bacillus coli than the water of the canal.

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10121. I am giving you a little instance: in the Dee you were not surprised that the mud contained a larger number of bacillus coli than the flowing stream?—I did not examine the mud; it is a supposition all through as far as I am concerned.

10122. But you would not be surprised in the case of the Dee?—No; I should not.

10123. I take it you would not be surprised in the case of the Manchester Ship Canal?—That it should contain some?

10124. Yes?—No; I should not.

10125. Well, do you regard that at all as constituting a practical danger?—No, I do not see much danger in it.

10126. Do you think that practically speaking there is any danger of the sludge being carried down say into the estuary of the Mersey and getting along the foreshore and constituting a source of danger?—I think such a chance is extremely remote; I do not think there is any evidence of mischief.

10127. Do you think there is a possibility of contagion being spread by the sludge being gradually carried down, for you know sludge is carried into the estuary?—Yes, certainly. No; I do not think there is any practical possibility of any danger arising in that way. If there was any such danger surely the mouth of the Thames ought to have been a source of contagion for years. I do not think there is any evidence of the kind.

10128. Professor Ramsay asked you about standards, whether you had a bacteriological standard for drinking water?—He asked about a chemical standard.

10129. Have you got a bacteriological standard for drinking water?—No. If you take any ordinary surface water I think the application of any standard is quite out of the question, but after water has passed through any purification process, and the purification process is efficient the water ought to be nearly sterile.

10130. Well then what standard would you adopt in the case of a filtered water? What have you adopted in the course of your practice?—The nearer the water approaches to sterility the more satisfied I am with the process.

10131. How have you managed that?—By the number of bacteria which is calculable in a given volume.

10132. Have you limited yourself to a particular species of bacteria, or certain species being present in one cubic centimetre?—I took the hundred per cubic centimetre for a rough test. Indiscriminately applied it is capable of doing a great deal of mischief.

10133. Why do you think it is capable of doing a great deal of mischief?—Because it may lead to a suspicion where no suspicion is needed at all; and what is more important the water must be examined immediately it comes from the purifying process, which is very often not done.

10134. But granted all that you think it is really misleading, the estimation of numbers in drinking water?—It may be very misleading—yes.

10135. It may be very misleading?—Yes.

10136. In other words you are very clear that the sources of the water must be known?—When I say misleading it is on the higher standard that the liability to fallacy comes in. These bacteria which are found in the effluent from a filter may be derived from the lower strata of the filter itself and not have anything to do with the original bacteria in the water.

10136*. I understand what you mean?—The bacteria detached from the lower parts of the filter which may occasionally increase in number and which do not indicate that the filter is operating inefficiently at all.

10137. Would you lay any stress on the presence of the bacillus coli in such drinking waters?—I would lay stress on it insomuch that I prefer a water not to contain it.

10138. For what reason do you do that?—Because here is a definite species of bacterium which must have been in the water originally and it has not been removed in the process. Bacillus coli does not multiply in the water so that it cannot become detached from the lower parts of the filter because it could not be in the lower parts of the filter, it could only have got into

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the lower parts of the filter through passage from the upper parts.

10139. But you have said that the bacillus coli was widely distributed (*see* Questions 10104 and 10105). I do not think I follow the answer?—It is widely distributed over the surface of the land—yes.

10140. But I do not see quite that under these circumstances you lay any stress upon it appearing in the filtrate?—Yes, because here is a distinct organism which has not been removed in the process, which was in the water to begin with, and which has passed the filters. Now many of these other organisms can multiply in the body of the filter or in the filtered water itself with great rapidity, but there is no evidence that the bacillus coli can do that.

10141. You have made no observations on the pathogenicity of the bacillus coli?—No observations.

10142. Have you made any observations on the bacillus enteritidis?—I examine for them in drinking water.

10143. And do you put it on the same level as the bacillus coli?—Yes; I prefer to see it absent.

10144. But apart from that, apart from preferring to see it absent, you do not lay much stress on it?—I do not think the evidence is sufficient yet to be able to say that the water which contains that ought to be condemned.

10145. I would much like to ask, in the case of the River Thames, whether you could tell us whether you found the bacillus coli in one cubic centimetre, because it is rather important. Do you find bacillus coli in the Thames water?—I have not examined the Thames water for coli.

10146. Do you think from your experience that it would be advisable to sterilise the effluent from contact beds or similar methods of sewage treatment if the sewage came from a fever hospital with a large number of typhoid fever patients, and if the effluent had a chance of getting into a stream used for drinking purposes?—Well, I think it would be distinctly reassuring if it were sterilised.

10147. I mean is that a case where you think that sterilisation would be of practical utility?—Where you had the effluent simply from this hospital?

10148. Yes?—Oh, I should think certainly it would be of utility.

10149. You have made no observations on the bacillus typhosus in effluents, I suppose?—No, only in drinking water.

10150. And you have not found it or have you found it?—No, I have never found it.

Dr. JOHN AUGUSTUS VOELCKER, Consulting Chemist to the Royal Agricultural Society, called in; and Examined.

Dr. J. A. Voelcker.

10151. (*Chairman.*) Is it from the point of view of an agricultural chemist that you have come to speak to us?—It is

10152. Would you tell us generally what sort of work you have done?—The work that I have had to do principally has been that of advising with regard to soils and their suitability for the purposes of sewage farms. Then I have had to report upon the working of sewage farms from the agricultural point of view, and also with regard to the efficiency of the filtration and purification of sewage. I have also had, not in my agricultural connection, but in my private work, to examine into different systems that have been used for the purification of sewage on sewage farms.

10153. You mean different artificial systems?—Yes; different artificial systems.

10154. With regard to sewage farms, I suppose you have a tolerably wide experience?—I have a very wide experience.

10155. Could you mention the names of any places?—I have visited at different times for the purposes of inspection the following places, viz.:—Manchester, Birmingham, Wolverhampton, Preston, Norwich, Reading, Guildford, Godalming, Southall, Nuneaton, Wimbledon, Walthamstow, Edenbridge, Desborough and other towns in Northamptonshire, in addition to a number of small villages—quite local matters.

10156-7. Have all these places got sewage farms?—Every one that I have mentioned has a sewage farm.

10158. Then in regard to artificial filtration; have you studied any on a big scale?—I could not say that I have on a big scale, with the object of comparing different systems. I have not had a great experience in that respect.

10159. Have you had any experience in comparing sewage farms with artificial filtration?—You mean, I take it, apart from the use of the sewage on the land as well?

10160. Well, the point I want ultimately to get at is whether you think as good an effluent can be produced by artificial filtration as by land treatment?—I have a very decided opinion upon that point. From what I have seen of, and had to do with, purely artificial systems, I should not be satisfied with them unless there was land treatment in addition. Of course, that would imply a certain amount of farming.

10161. You would not be satisfied with artificial filtration alone?—No.

10162. Do you consider that you have examined enough instances of artificial filtration to give a positive opinion to that effect?—I should not like to speak positively at the present time, considering, of course, that there are many new systems. I would not like to give too definite an opinion upon that point at present. I would rather put it generally, that, having already had considerable experience in examining from a chemical point of view the effluents produced by purely artificial systems I am not as yet thoroughly satisfied as to their efficiency, or as to the satisfactoriness of their constant regular working. So that, as at present disposed, I should say that I am not prepared to adopt any system that I have seen yet, without the addition of land treatment to some extent. I am perfectly prepared to say, however, that some of the more recent artificial systems which have been introduced would enable a very much smaller area of land to be taken up than was the case in the earlier days of sewage farms. I do not know whether I have expressed my views plainly?

10163. Oh, yes, but if you would not mind giving us a general statement of your views I think we should be very much obliged to you?—If I may put it first from an agricultural point of view, I am disposed to consider the profitable employment of sewage materials, whether solid or liquid, in this country as necessarily an item of considerable expenditure. In other words, I regard sewage as a nuisance which has to be got rid of, and the point is at what least cost can it be got rid of. I have had to do with many different systems for years past, which have had the object of producing either a rich effluent or of removing the solid constituents and employing them in the form of sludge. I should be disposed to regard one and all of these, financially, as failures, and merely as items by which the cost could be somewhat reduced. In brief, I should not consider that there was any system of utilising either the solid or the liquid portions which were likely to be in any way a financial success or an agricultural success, with the single exception of the utilisation direct of the undiluted sewage. From my experience in some parts of England, and from my experience in India, I should say that if it were possible to use night-soil direct and put it on the land, that is the only system which has any chance of being a benefit. In India it is an enormous benefit. It is very little exaggeration indeed to say that you might trace the best agriculture by the distribution of the night-soil. Where night-soil is used, there are the best agriculture and the best class of cultivators. The only approach on a large scale that I have seen to that in this country is the effort made to use the night-soil of one portion of the City of Manchester, as was done, and, I think, is still being done, at Carrington Moss. I do not know whether that has been before you, my lord.

10164. Yes.—I mention that because agriculturally that was a success—a brilliant success. Apart from that instance of the working in a large city, in my view the only instances in which night-soil could be used direct would be in small villages where you could use the earth-closet system. I have seen that in many villages, chiefly in Buckinghamshire, but also in dif-

ferent parts of the country. If you could get the people to use earth-closets, I believe then that the night-soil could be used to agricultural benefit, and with a minimum of nuisance. But with these exceptions I think one must regard any prospect of the utilization of sewage profitably in an agricultural direction as almost hopeless. It comes, I think, to a mere reduction in the necessary outlay. How far that reduction will go must depend upon two main factors—first, the nature of the sewage that has to be dealt with, and, secondly, the kind of land and the working of the farm upon which it is put. Speaking generally, I believe that sewage farms, from an agricultural point of view, may be carried out in such a way as to bring in considerable returns, looking at it, of course, as I said, in the way of a small reduction of expense. I also believe that that could be done as well on sewage farms, where land and situation are suitable, in such a way as to give a perfectly good effluent, and cause practically no nuisance whatever. But a further limit to this is the nature of the sewage with which you are going to deal. As I said just now, I think the days of utilising night-soil are practically gone, except in small villages, and for the advantages of having everything taken away from our houses as soon as possible we must resign ourselves to the water carriage system, and face the natural loss which must be coincident with that. Where you have got a purely domestic sewage and a population not too large in number—such, for instance, as exists in many rural districts—I am still a great believer in the utilisation of the sewage in its natural state without the intervention of precipitation of any kind, which means a large outlay on staff and works, and difficulties in dealing with the material, whether liquid or solid. I still think that the simplest way in many rural districts is to take the sewage as carried down the main sewers, simply to strain from it floating matter, such as corks, bits of wood, and other materials which come down with it, and pour it straight on to the land. It is not very material to my mind whether you have that land arable land, upon which crops are growing or to be grown, or whether you have suitable grass-land, on the slope of a hill, for instance, where you can pour the sewage down, and let it be distributed all about. I have known many instances of both of these kinds of disposal, and where in rural districts you have a population that is not too large to deal with, and where the sewage is of a purely domestic nature, I still think it can be dealt with in that way; and when it is so dealt with I think there is a considerable amount of good that can be produced in respect of the crops or the grass which will be grown on that land. The condition, however, for success is that the soil and situation should be of suitable nature. Perhaps I may illustrate this best by giving an instance of one farm, where such has been done. I would instance the small town of Desborough, not very far from Kettering, in Northamptonshire, which farm I went to inspect in my professional capacity. I found there a farm of four acres in extent, dealing with a population of 3,000 people, and dealing with it in a most satisfactory way. There was no precipitation. The only thing that was done was to strain the sewage as it was delivered on the farm from floating matters, to pass it into one tank which might be called a settling tank, from which the deposit was at times removed. After a short subsidence there, the sewage was poured down over the land, and, as I say, was most efficiently dealt with. The whole secret there was that you had a beautiful piece of land for the purpose. There was a nice rich sandy loam, fully four feet in depth, rich Northamptonshire land. I had occasion to make analyses of the sewage and of the effluent. The sewage was one of fair strength for purely domestic sewage, and the effluent as it went into a stream at the bottom of the sewage farm was very well purified indeed. Some statements having been made that cattle were being injured by drinking the water of this brook into which the sewage was passed, I had occasion to examine the stream both above and below the outfall, and to take samples from the outfall itself. I have these and other analyses before me, but I may say in a word that the working of this farm was excellent. I hope it will not be taken, of course, that I am advocating that anything like 3,000 people can be dealt with on four acres of land. I simply give that as an instance of what can be done where land is suitable, and where the farm is, as was the case here, managed by a competent man who knew his business. If you have such conditions, I still believe that you may very easily deal with the sewage in many rural districts in such a way as I have indicated. An instance of another kind is where the sewage has been simply poured down the side of a hill covered with grass—a grass hill with a stream running at the bottom of it. There, the sewage will flow through the first six inches or foot of the land; there is no question of drainage below; and, passing through the land, it simply flows continuously down, and by the time it reaches the stream, if the land be in any way suitable for the purpose, you may get very excellent purification, and you may also get very fair returns from the grass that is grown, with an entire absence of any nuisance. I have had occasion in many rural districts to recommend this to be done. The fault of many of these systems is that people think that they have only to turn the sewage on to a grass field and leave it there, regardless of whether it soaks in, or whether the land is subject to water-logging, or whether the stream is suitable, and so on. It is not to be supposed for a moment that you can turn sewage on to any grass field anywhere, and expect it to find its way through. Therefore, if I may sum up my views as regards the sewage of rural districts, I think that where the population is not too large, where the sewage is of a purely domestic character, where soil and situation are suitable, the cheapest way is still to turn the sewage straight on to the land; in other words, to deal with it by broad irrigation. That may be done at very small cost, and very much less expensively than by going to any system of precipitation, which, in my opinion, is really not called for yet in rural districts. Then you come to a larger class when you deal with the question of towns. In towns you have more difficulty in procuring land, and very often you have to deal with a soil that is not naturally suitable, you have to take the soil that you can get. That is the real difficulty in regard to sewage disposal in towns. Leaving out for the moment the complication of it with manufacturing refuse, you have a very large volume—a very much larger volume to deal with than you have in rural districts. Therefore, I think you must adopt some system of settlement and remove the solid matters before you turn the sewage on to the land, or, as an alternative, you must adopt some system of precipitation. Of all the systems of precipitation I still think the simplest one is that of lime precipitation. I have had to deal with other systems in which sulphate of alumina and other chemicals have been used in conjunction with lime, and although there may occasionally be cases, especially where manufacturing refuse comes in, in which these can be usefully employed, on the whole I still consider that the simple precipitation with lime is the cheapest and the most easily dealt with. Where you have such systems I should certainly, in the light of what has come to us lately in the way of knowledge, have, combined with such a system of either settlement or precipitation, filtration through coke-breeze filters. These, I am convinced, do a great deal of good. Like all filters, much depends on whether or not they are kept in order. I have examined several systems of filtration, and in many cases I have found them very unsatisfactory, but I am by no means going to say that it is the fault of the filter itself. It is very often due rather to the way in which the filter has been worked. But, speaking generally, I think the introduction of coke-breeze filters has very much simplified the question of filtration. As I said, too, I think that if you do have any of these systems of filtration, or bacterial methods, as they are now called, I should certainly like to see them supplemented by treatment on land subsequently. That leaves the last class—the towns and cities—where you have largely to deal with manufacturing refuse. There, I think, the problem is very much more complicated, and it is equally complicated for the purely artificial systems as it is for the purely natural system of land filtration. The great difficulties with regard to the land are that you are dealing with materials which block up the land mechanically. You are dealing with materials which produce a scum on the top, which prevent the circulation of air through the soil, and impair the efficiency of the land for filtration purposes. The same elements introduce difficulties in regard to the efficient working both of precipitation methods and of filtration methods, even through coke-breeze and other similar filters. I think you must take it for granted that where you are dealing with manufacturing refuse, whether you employ precipitation or artificial filtration, you must be prepared to use a larger amount of land than you would under ordinary circumstances. I have had experience—I will not trouble you

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now with details unless they are desired on any particular points—where I have had to deal with manufacturing refuse in connection with sewage in the case of several different kinds of works throughout the country, and upon which I would give any information that was in my power. I think the only thing further I have to say is with regard to the crops that might be grown where land filtration is used. The range naturally is a limited one. The great thing is to grow crops which are of a succulent nature. The utilisation of these crops, again, is another question. The great use of rye grass and Italian rye grass is, of course, to give green fodder in springtime and on throughout the summer and the hotter period. One of the most profitable crops is mangel, and sewage farms such as those at Reading, Norwich, and other places show very well what can be grown in the way of growing mangels. They grow very fine specimens. I am not going to say that they are always of the best quality, but, judged by size, at all events, they are fine specimens, and where a farm can sell them by weight they may very considerably reduce the expenditure on a sewage farm. The growing of vegetables can also be carried out very largely. Cabbages are rather a favourite crop, and carrots I have seen grown, and many of the ordinary crops of a farm, such as potatoes, wheat, and oats, can be grown. With regard to these last mentioned, of course, I must put the reservation on them that they are not grown on the land on which the sewage is actually being poured. A very frequent practice is to have the sewage going on one-half of the land one year or one season, the other half being left dry. At Norwich, for instance—I have been over the farm there several times—the general system is to grow mangels where the sewage is actually being poured on, and the other half of the land is grown in oats. The oats are cut, and after harvest the sewage is turned direct on to the oat stubble. It is poured on all through the winter, so that in the spring the land is ready to receive its mangel crop, and the other half grows oats. I do not think myself that there is any very particular point with regard to the growing of one crop rather than another on a sewage farm. It is rather a matter of management. Where you have a good agriculturist in charge of the farm, he will see to it that the crops are grown which are best suited. There is only one matter further with regard to the cropping of a farm to which I wish to refer, and that is a rather unique case, which has always been somewhat of a wonderment to me—I refer to the case of the Norwich sewage farm. The sewage of Norwich is pumped up from the city to the top of a hill, and is poured down over acres of grass. Open channels are cut, and the sewage flows perfectly open in them. Feeding all over the sewage farm are cattle—cows, the milk of which goes into Norwich. How it is that the cattle never get ill has never been exactly settled, but the fact remains that there is no trouble whatever with them. I know that on the visit of the British Dairy Farmers' Association to Norwich the members were all very much horrified at such a thing as this going on, that the sewage of Norwich should be open to the cows which were supplying milk to the whole town. But I am glad to say that there has been no case of illness either of the cattle or in the town through the utilisation of the sewage direct on the land in this way.

10165. You have never known a case of a cow or of any animal falling ill through feeding on a sewage farm?—Oh, yes, when feeding on a sewage farm.

10166. As a result of feeding on a sewage farm?—No, I could not say that.

10167. Or of drinking water contaminated by the sewage?—Yes, I have had cases of that. Oh, yes; I have had many cases. I have had many cases in which I could speak of cattle having been injured through drinking water into which sewage effluent has passed.

10168. Then if cattle drank of the stream into which the effluent from your sewage farm goes, if that effluent is not a good one, there would be danger, I suppose?—I certainly think it is a source of danger.

10169. And would you say that for the successful management of sewage farming you must have an expert to manage the farm?—An expert?

10170. Yes. As I gather it, your view would be that a sewage farm must be managed, not with a view to the profit that can be made out of it, but with a view to treating the sewage properly?—Yes, certainly.

10171. Well, then, in order to treat sewage properly, you must have a man who properly understands it?—I certainly think that. Except, of course, in rural districts, where you put the sewage direct on to the land. There I do not think it would be necessary. I should make that distinction.

10172. Yes?—Where you have a small rural district and are simply dealing with the sewage direct on the land—what you want there is more a good agriculturist than anything else—a man who is up in his agriculture, and who knows something about the drainage of the land. But as soon as you get to towns of any size, I think the employment of an expert is an absolute necessity. As regards the failure of many sewage farms—I could give instances of it—of course, in some cases it is due to their having been laid out wrongly, but in most cases it has been due to the improper management of the farms by the men who have been in charge of them.

10173. Then do you consider that all kinds of soil can be used for sewage farms?—Certainly not. I do not think that all kinds of soil can be used for sewage farms, but the difference I consider to be more a question of the area that you would require and the system that you would adopt on that land—whether underdraining it or not—than anything else. For instance, if you have a light sandy soil, without any "substance" in it, almost a sand, you may get sewage running through it, and you may get it mechanically arresting some of the materials, but you may get a very small amount of purification. On the other hand, if you get a more loamy soil, you will have there a very much better surface on which to work. I have a very good example, if I might illustrate the point by the instance of the Preston Sewage Farm. That farm was originally a very light sandy land, and the difficulty with it was to get any "substance" into the sand. At first it did not act very well, but it was found that by running the sewage into a sort of settling tank and then taking the solid material out of the tank and digging it into the land, they then got a very much better filtering medium than before. The sewage farm was more efficient as a filtering and purifying medium after the sewage had been dug in than it was in its original condition. In other words, soil had been formed. Where, however, you have a nice, rich, deep loam, not too light and not too heavy, there you have, in my opinion, the ideal conditions. On either side of that you go to extremes. You may have land which is peaty—very unsuitable indeed. Then on the opposite side you may have land which is clayey—equally unsuitable. Clay, of course, is open to the great objection that in hot weather it cracks. If you drain it underneath you will get the sewage running straight down to the drain without going through the land at all. But I think that all lands are capable, more or less, of effecting very considerable purification if they can be mechanically adapted to it by proper cultivation and so forth. After all, the purification goes on not in the lower layers, but in the upper layers, and if you can by cultivation get your soil to act as a filter, and as a purifying medium, I think that even on a soil that you would not take by choice you can effect a very great improvement, but you may have to use a much larger area of land.

10174. (*Major-General Carey.*) Of course, the whole success of sewage farming depends upon good management?—I think so.

10175. You may have suitable soil, but with indifferent management even that farm will be a failure?—Quite so. I have seen many cases in which that has occurred. Of course, in many instances the fault has arisen from there being an insufficient area to start with.

10176. Yes?—Down comes the sewage, and what is the man to do?—He lets it go straight to the stream, and it does not have the chance to be purified. You could hardly blame the man for that, but the management has been responsible for it.

10177. Of course, there are frequently cases in which it is practically impossible to obtain land?—Yes, that is so.

10178. Or, if the land can be obtained, it is not of a suitable character?—No, not of a suitable character.

10179. In such cases preliminary treatment of some sort must be adopted?—I quite think so.

10180. Either bacteriological or chemical treatment—some preliminary treatment?—I quite think that.

10181. If your place is so situated that the only land available in a small area of stiff clay land or peaty land

or waterlogged subsoil, which cannot very well be drained, you must have some other means of purifying your sewage?—I should doubt very much whether there were many cases in which the land was not very suitable, or, at all events, where land that could be utilised could not be found. I do not think the cases are many in which you would find yourself in such a position that you would be obliged to resort only to artificial means. I could not mention any places myself.

10182. (*Professor Ramsay.*) We have been informed of some valleys in Wales—in Glamorganshire—which apparently are very rocky and very narrow; they are a long way from the towns, and very thickly inhabited by a mining population. There it appears that no land could possibly be obtained?—In hilly districts?

10183. The rocky sides of hills——

10184. (*Major-General Carey.*) Narrow valleys, with steep sides, and probably rocky?—Then you would have to do what you propose.

10185. (*Mr. Killick.*) Or some of the narrow valleys in Yorkshire, which are of stiff clay; what would you do there?—In which part of Yorkshire?

10186. The West Riding?—Yes, but I should not consider the majority of the soils in the West Riding of Yorkshire to be so stiff as to be unsuitable.

10187. I did not say the majority, I said some?—Some, yes.

10188. (*Major-General Carey.*) If suitable land can be obtained at reasonable cost, you prefer it to any other method?—Yes, certainly. There may be cases in which one would have to resort entirely to artificial means, because no land was available. In such cases you would simply have to do the best you could. But you will not, I think, get such a satisfactory effluent, and you may also lose a certain amount of agricultural benefit from the crops grown, which you would derive if you combined the two things.

10189. With regard to the cereal crops, is not the great defect that no sewage can be applied to them for a very long period in each year?—They have practically to be left.

10190. Practically the land on which cereals are being grown cannot be used for the purification of sewage?—Where cereals are grown for corn?

10191. Yes?—Yes, that is so.

10192. For purposes of the purification of sewage, you would have to be independent of the land occupied by these crops?—Where you have plenty of land, and can get enough land to give it a rest for the winter season, you will not find your cereal crop suffer at all by the fact of sewage having been on it. You cannot pour the sewage on and keep the ground constantly wet, but if you have enough land to keep the sewage off it for the season of the cereal crops which are grown, you may get very luxuriant crops—more luxuriant than you would on many other lands.

10193. That is, assuming that you have sufficient land to be independent of the land occupied by your crop?—Quite so.

10194. I have only one other point. You mentioned lime as a precipitant. I think you said you had no objection to it. But does not lime create a very large quantity of sludge of which it is difficult to dispose?—Yes; but I think the addition of any chemicals—lime or otherwise—introduces difficulties.

10195. But lime especially. The amount of sludge produced by lime is larger than that produced by any other chemical precipitant, is it not?—I could not say from my own experience. On the other hand, the use of lime as a precipitant, and the mixing of the lime with the soil afterwards in the form of sludge, is in many cases very beneficial indeed to the land. Land, in many cases, suffers very much from the absence of lime, and it is not at all an inconvenient way of supplying lime to the soil, whereas the other chemicals have no agricultural value at all.

10196. (*Professor Ramsay.*) In India the caste system presents a strong barrier to the utilisation of night-soil, does it not?—Yes, it does. There are only a certain class of people who are allowed to handle it.

10197. Agriculturists will not touch it very often?—But a very considerable change of feeling has come over many agriculturists of recent years. I know many agriculturists now who years ago would not have thought of using night-soil, but who now do use it.

10198. In India?—In India.

10199. As regards the disposal of the sewage of large populations, such as there are in Calcutta and Bombay, do you consider that there is any possibility of it being done there?—It is an impossibility with regard to such large places as Bombay. But, on the other hand, Poona has been for many years most efficiently served, and the utilisation of the night-soil by the municipality has been a great agricultural success.

10200. Yet they are just starting a huge drainage scheme?—Quite so; and the same thing applies to Cawnpore. When I was in India, a scheme for introducing a water-carriage system for sewage was just being introduced at Cawnpore, Allahabad, and other places. I took occasion then to write about it, and I always regarded it, and do still regard it, as a great agricultural mistake. But there it is; we have evidence of it here; it is one of those things which are bound to go in the case of towns that are increasing in size, and especially where you get more and more of an urban population. It forms part and parcel of the system of water supply for drinking purposes. That has brought a great revolution. I know that in Cawnpore when they have this water supply system—a water supply in the houses—agriculture will go. So in this country too. If we were to consider this matter purely from the point of view of what we could get back from it, if we could get back the earth closet system, and everybody would adopt it, it would be the simplest plan, but the feeling is very naturally against it. I am sorry that it is so, but it is one of those things which have to go, and it will go in India in big towns in just the same way as it has in England.

10201. Yesterday, we had evidence from Dr. Poore with reference to the disposal of night-soil in small quantities in villages. Do you not think that the best way of introducing that—for one cannot make compulsory legislation on the subject—would be, educationally, to try to get teachers in elementary schools to instruct their children as to the easiest way of disposing of night-soil, and the immense increase of garden produce which they might expect to have by its utilisation?—I am afraid I have very little hope of much spread in that direction. I know Dr. Poore, and I was very interested in seeing his garden worked on the system he has described; it is very nice indeed; and if everybody were to do it it would, no doubt, be a very simple system of disposing of the sewage, but I have not the least hope that it will be generally adopted.

10202. (*Chairman.*) But is it not your experience that an ordinary agricultural labourer with a garden of his own uses the sewage and digs it into his garden?—No, I am afraid it is not. My experience is that when there is put up, as is done under the new regulations, on the other side of the road very often, or at the end of the garden, some nice building, and the man and his family are expected to go out there at night, if they can find some other place to dispose of their refuse in they will do it. I am afraid I have very little hope of getting the people in rural districts, whether they are labourers or gentlefolks, to adopt any system other than that of water-carriage if you give it to them.

10203. I am talking of where there is no water-carriage system. In labourers' cottages there is no water-carriage.—No, there is no water-carriage, but I think people in the country generally still have the old cesspool, and would rather stick to that than have anything to do with these new ideas. I do not think there is any chance whatever, either by education or by example or otherwise, of doing very much in the way of improvement in that direction.

10204. It is a common practice, I think, in our villages, to have a pit—not a cesspool, but a pit, on the level of the ground, and then at certain intervals, whenever it wants it, they empty it out, and dig it into the garden?—They dig it into their garden.

10205. Yes.—But you are speaking of it, I take it, from the point of view of profit—whether you are going to use it profitably, or whether any advantage is going to acrue from it.

10206. They consider it valuable as manure.—They consider it valuable in a way, but what is their practice? Their practice is that it all goes into one place, and nowhere else. It is not utilised in the right way, and I do not think you will get people to utilise it very much more.

10207. (*Major-General Carey.*) It is not spread over the land?—It is not spread over the land. Your Indian cultivator knows to a nicety what to do

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with it. Give him the night-soil, and if he is of the caste that is allowed to touch it he will use it so that it is distributed well over the land; he will take it away himself, and is glad to do it. But in our country towns and rural districts here you will find such a state of things as your Lordship has described; when the night soil is taken away it is never properly utilised, it is simply put on one part of the land, and that is where it all goes; there it is put on year after year, and generally the well is somewhere near it also, and you get the whole benefit of it in that one spot.

10208. (*Professor Ramsay.*) With regard to the use of night-soil, is domestic sewage sufficient for manure, or is it mixed with nitrates, or phosphates, or what?—No, for general agriculture it is not. The only case in India that I know of, in which night-soil is supplemented by anything else, is for very special cultivation, such as that of sugar cane. I consider that the return of the night soil to the land in the way that is done in India would solve the whole of the agricultural difficulties.

10209. I am speaking of this country—of sewage farming in this country?—In this country? Oh, I do not know of any case of sewage farming in this country where it has been found necessary to supplement the sewage.

10210. Can you classify soils as to their suitability for sewage farming purposes?—The difficulty of classifying them is that you do not have the same kind of soil all over an area; you will have perhaps two or three different classes of soil.

10211. Yes?—I have brought with me, to illustrate this point, the sequence of some soils that were taken on a proposed sewage farm. I had the soils to examine, and I made analyses of them, and these go to show that in quite a limited area you have quite different classes of soil to deal with. In some cases you have a nice loamy soil at the top, then comes another class of soil, which in turn rests on a rocky soil. Then you may get a concretional mass formed, which upsets the whole working. But, to put it generally, I should say that you get two extremes. The first is a soil which is so charged with vegetable matter—a peaty soil—as to be unsuitable on that account, or a sand which has not enough "substance" in it to hold the material passed through it. At the other extreme, you have a clay which is not sufficiently porous, a clayey loam, with a clay subsoil, which forms an impervious base. Between these two extremes you would have soils which you would class generally as sandy loams, loams, or clay loams.

10212. Which would be suitable?—All of which you might use without hesitation—some better, of course, than others. But very often the local differences as you go down will make considerable variations.

10213. Have you any special tests for the soils in the shape of water-holding capacity, or something of that kind?—Yes, I have applied that in many cases—taking the soils, and finding how much water they will hold, and weighing them; I do that in conjunction with what you may call the mechanical testing of them.

10214. Yes?—I supplement that also by separating the soils into their mechanical constituents of sand and clay, and I also make chemical analyses. So that if I had to judge of the quality of a soil, I should try its water-holding capacity, its mechanical division, and its chemical composition. In special cases where special effluents have to be dealt with, I am quite certain that nothing except a practical test with the material that is to be dealt with is satisfactory. I had a very clear instance of that in a case where I was dealing with the refuse from a margarine factory. I took soils from a sewage farm, and there I found that the different parts of the land varied very much in their power of holding back or of letting through into the stream finely divided matter.

10215. Do you consider that a sewage farm, as a rule, should be underdrained?—As a rule, I might say it should be underdrained. But in the case of very heavy clay soils I should not advise it, because of their liability to crack in dry weather, thus allowing the sewage to go through unpurified. I think underdraining in some cases may do very much more harm than good. I think there are instances on record in which the drains have actually been taken up, and the working of the sewage farm improved very much in consequence.

10216. Is it possible to render the surface of a clay soil more suitable for sewage purification by the process which you have described? You speak now of clay soil in particular. You told us of sandy soil which would be greatly improved. Is it possible to improve clay soil in that way?—My reference was to heavy clay soil.

10217. I thought it was the sandy soil which was improved?—I intended to refer to heavy clay soil. Speaking generally, I should not drain sandy soil at all. On my own farm—I am speaking of an agricultural farm—I have no drains at all, and do not want any. I am quite certain that if I had drains there I should not only lose the moisture which came, but also the manures which I put on. So that I would say generally, do not drain sandy land unless there is need of it. With clay soil, drain it if you can get the soil to work in between properly, but if is a heavy clay soil, liable to crack in hot weather, you are better without draining it at all.

10218. Do you notice much difference in summer and winter as regards the purification effected by a sewage farm? In winter, does the sewage tend to run off the side of the land untouched?—I cannot say that my attention has been drawn to that point particularly.

10219. Does the application of the sewage sludge to the ground do any harm to it?—I do not think so; in many cases I think it does good.

10220. In Birmingham they dig the sludge into the ground?—In Birmingham—if they have time to do it.

10221. Do they take crops off that land afterwards?—When they get time to grow them, yes. I think the digging in of the sludge is a good system. But everyone knows that they have very great difficulties at Birmingham, and I believe they are not able to cultivate the whole of the land which has the sewage sludge dug into it, or to get it into proper order. To speak of the system agriculturally, there is no reason at all why it should not be perfectly good, and I do not think that any harm would happen to the soil as a consequence.

10222. You spoke of the fact that you have not observed any disease due to cattle feeding on sewage farms, but I think you have noticed disease occurring among cattle which drank sewage?—Yes. In the case that I mentioned, at Norwich, the cattle are always going over the fields on which sewage has been poured. They have access to the sewage, but that they drink it I am not prepared to say.

10223. (*Dr. McGowan.*) They do drink it. (*Witness.*) I know that if you give cattle dirty water they will always drink it in preference to clean. But I maintain there is a very great difference between cattle which are always under one set of conditions, such as I have mentioned, and cattle which may be under perfectly normal conditions, and then are allowed access to such a thing as polluted water. If, for instance, you have cattle on land which is sodden, such as that on the sewage farm that I speak of, they may get perfectly well accustomed to those conditions; whereas, if you take other animals from other conditions and put them on the same land they may very soon suffer from it. That is the only way in which I can account for the fact of cattle, I will not say having been killed, but having suffered from getting access to water into which polluted matter has certainly gone.

10224. (*Mr. Killick.*) Could you tell us the character of the illness from which the cattle suffered?—No, I cannot speak at all from the veterinary point of view. My reference was to cases in which I have been concerned, and in which veterinary experts have been concerned with me. I have given it rather on their evidence than my own. I have always been careful to speak purely from the chemical side, and never to express an opinion in Court as to whether an animal has died of this or that particular thing. It is out of my province. I have shown frequently in such cases that the water taken from a certain point where the cattle had access to it has differed from the water above the source of the pollution by reason of the incoming of the polluting matter. But, except in cases where I have found evidence of the killing of an animal through the presence of metallic poisons and the like, and where I have examined the viscera of the cattle chemically, and found these poisons present in them, I could not say that I have, apart from the veterinary evidence, anything really to go upon in that respect.

10225. Have you ever found anthrax to exist?—Yes, I have a case of that in hand now.

10226. Can that be traced to sewage contamination? Are the cattle which suffer from anthrax on sewage

farms?—I do not know. I do not know a case that can be substantiated as having been derived from a sewage farm. I could take you now to Yorkshire, and point out to you a field where anthrax has been for years past; you can get it out of the soil. And the same fact is known in regard to India—cattle suffering from anthrax have died and the bones have been scattered about. This is one of the objections to the use of Indian bones, that you may carry anthrax about in that way and deposit it on the fields. But I do not think there is anything to be put down peculiarly to sewage farms more than to any other source of that kind.

10227. (*Professor Ramsay.*) You spoke of having two classes of men to manage sewage farms—if they were very small, an ordinary farmer; but if you are dealing with towns, an expert. Does it not appear to you that to manage a farm profitably is what a farmer would like to do, but to have to manage it unprofitably revolts the very soul of a farmer?—If you are managing it for a township you probably do not know how it is going.

10228. It falls to two very different classes of men—the one farmers and the other not farmers?—Farmers nowadays are getting pretty well accustomed to farming without making it pay. I do not think the manager of a sewage farm would be particularly depressed.

10229. But a farmer will always try to make it pay?—Yes.

10230. But the man who wants to dispose of sewage need not try to make it pay, and he will view his farm solely from the point of view of disposing of the sewage?—Yes. I know cases where the efficient working of the farm as regards the proper purification of sewage has been injured by the consideration of the tenant or the man working it for the sake of making a profit. Most of the instances, in fact, that I can call to mind at the present moment are cases in which the district council has taken up land and poured its sewage on it, and has let the land to somebody else who is not in the service of the council, and who has taken up the land as a farm. There he will grow his crops, and he will put the sewage on it when he wants it. When he does not want it he will put it down a side path straight into the stream. I have many instances of that that I could name, where the efficiency of a farm has been brought into bad reputation entirely through the fault of the district council, or whatever other local authority it may have been, in not taking up the farm themselves and working it by proper officials of their own, but letting it out to somebody to farm for them. The case at Preston that I mentioned a little time ago was such an one. What happened there was that the Preston Corporation let out their land to somebody to farm for them. The man farmed it as a farm. A portion of the land was not suitable at first, through being too sandy. The tenant let the sewage stand on the land, and collected all the solid matter he could and stored it in great lakes. That, in the opinion of some, produced a nuisance, and they said they could smell the sewage for some distance off. People objected to this, and there was a law case as the result. The farmer found that he could not deal with the sewage properly on the very sandy land, but the land after he had let the solid matter go on it was very much richer, and so he preferred working the farm in that way. That was very nice from an agricultural point of view, but not from a health point of view. Thus the two interests were in conflict. I strongly advised the Preston Corporation to take the management of the whole farm into their own hands. Their business was to get rid of the sewage nuisance as cheaply as they could, and their first point was to manage it as a sewage farm rather than as an agricultural success.

10231. In the case of manufacturing refuse, do you think that under any circumstances a farm can dispose of manufacturing refuse?—I will not say that it is impossible, but I say that the difficulties are very much increased. You have to take very much more land for it. I have had to do quite lately with some such cases, and I mention this here because I have heard it stated in evidence that no more land is required for certain forms of manufacturing refuse. I am referring at the moment to tannery refuse. I have heard it stated that no more land is required for the treatment of tannery refuse than for the treatment of ordinary domestic sewage. I am directly opposed to that statement. It is impossible to deal with it on the same amount of land; it becomes another matter altogether.

10232. (*Major-General Carey.*) With careful precipitation?—There should be precipitation, but that applies to all manufacturing refuse. I hold that before manufacturing refuse goes down to mingle with the sewage it ought to have a preliminary treatment of some kind—either precipitation or some chemical treatment suited to that particular class of refuse. That should be done before it is allowed to commingle with the ordinary sewage. I know that the difficulties of corporations, and even of district councils and other local authorities, have been immensely increased by the putting of manufacturing refuse down the sewers at all manner of times without the control of the local authorities. The great difficulty in connection with manufacturing refuse is this: it is not like the sewage—a regular flow at certain times. It is not under control. It is sometimes let down in a large volume, and then it may stop for a time. Supposing you have got something which is harmful to the land. Down comes a certain volume of that, and the land is spoilt, and then you expect it at once to resume its working capacity. If you make any complaint about it you are told that the volume of it is very small compared with the sewage which comes down with it. But you have introduced a totally different set of circumstances. It may not be a large amount if you spread it over the whole of the time, but when you get a sudden burst of manufacturing refuse, and little or no sewage happens to be going down, you get as much refuse or more than you do of sewage. That is where the harm to the land and harm to the process of purification is done.

10233. Whatever the process?—Whatever the process.

10234. (*Mr. Killick.*) Is not that obviated, to some extent, by the use of tanks?—Theoretically it is.

10235. But is it not practically, as proved by experiments?—I have not seen a place yet where an ideal system of getting manufacturing refuse or even the bulk of the manufacturing refuse separated from the ordinary sewage is in existence. As a matter of fact, if you have your tanks, down the refuse goes whether the tanks happen to be full or not. I do not say that it could not be done, but I say that the man in charge of the works has got to get rid of the refuse, and the easiest way is to get it on to the land, and it goes down regardless of other considerations.

10236. (*Professor Ramsay.*) I do not think you quite understand the question. The question as regards this settling tank was that the sewage and manufacturing refuse might become uniform in composition?—Yes, that is practically what I was trying to answer. It is a question whether you can get enough tank room. The tank room must be sufficient to hold your maximum quantity, and to let it settle there as long as you want it. I have not seen yet a place where the tank accommodation is large enough to hold the maximum amount at any time of the year and the sewage as well. Where you have storm water coming along with the sewage the problem is enormously increased. You get a heavy fall of rain, and you get your tanks full very much sooner than you expected. What is the man in charge to do with it? That is the practical question. I think the much easier way, and the much more satisfactory way, is to make it compulsory that the manufacturing refuse should be dealt with on the spot, and undergo a certain amount of purification before it enters into the sewage.

10237. (*Major-General Carey.*) By the manufacturer?—Yes, by the manufacturer.

10238. If you can compel him to do it?—Yes.

10239. If it is entirely voluntary there is always the risk that they will not do it?—They will never do anything voluntarily.

10240. (*Professor Ramsay.*) What test do you generally use for sewage effluent? What do you generally estimate?—Generally I estimate the matter in suspension, the nature of that—whether organic or mineral. Then I examine the filtered material, determining in that the solids, the lime, magnesia, sulphuric acid, nitric acid, chlorine, and silica; these are the usual mineral constituents I determine. In addition to that I determine the organic matter, or rather, the amount of oxygen absorbed in a certain time.

10241. From permanganate?—By permanganate, yes.

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I determine the free ammonia and the albuminoid ammonia, and of recent years I have determined the amount of aeration.

10242. Is there any test you can suggest which would be convenient, say, for a farm manager or some non-chemist, by which he could reach some sort of idea as to what was going on in his farm effluents?—No; I do not think it is at all necessary that he should. The variations are so enormous. I have had to do with different sewage going on at different times, and it is very hard even from a chemical point of view to get any idea as to what the nature of sewage is at any one particular point. It is only by a series of examinations that it can be done.

10243. I do not mean the sewage, but the effluent; if the agriculturist wants to know whether it is up to a given standard of purification, or whether it will turn out unobjectionable or objectionable?—You are speaking, I think, of sewage going on to the land?

10244. I am speaking of the effluent from the land?—Oh, of this effluent?

10245. Yes. For instance, you have got a farm labourer who is not a chemist, and you want to put into his hands some sort of test whereby daily he shall know whether he is fulfilling the purpose he is placed there to fulfil?—My experience is that they have a very good idea whether it is what ought to go on or not, and I should be very sorry to try to make chemists out of them. I think the ordinary indication of freedom from matter in suspension and freedom from smell are about as good ones as either he or a chemist could have.

10246. Yes?—I do not see that very much advance would be made. Even speaking as a chemist, I should attach more importance to the observation of my eyes and my nose as to whether it was a pure and proper effluent than as to whether it contained this or that number of grains per gallon of this or that constituent.

10247. (*Mr. Killick.*) You have enumerated several different kinds of trade refuse which are difficult to treat. Have you anything to say about each special class? For instance, brewers' refuse?—Brewers' refuse, yes; I have had to do with that. I have had to deal with brewers' refuse at Guildford, where it constituted a very great difficulty.

10248. The difficulty consisting in——?—The difficulty consisting in the blocking up of the sewers, the very objectionable smell, in consequence of the fermentation going on after the mixing of the sewage with the yeast washings and other brewery refuse.

10249. What remedy did you suggest?—The remedy there adopted was a voluntary one on the part of the brewery people. They separated the solid matters on their own premises, and they put them there on filters—I think they were coke filters. They were only beginning to do it when I was last connected with the matter. That I know was done.

10250. Tannery refuse is simply, as I think you said, rather worse to treat than sewage; it would be treated in the same way?—Tannery refuse I consider a very difficult thing to deal with. The difficulty with tannery refuse is that it is, in my opinion, a very bad thing for the land. You are dealing with two different kinds of liquor in the effluent at one time. You have one material which is of a strongly acid character, highly charged with vegetable matter, and on the other hand you have lime washing, which is of just the opposite character, strongly alkaline. If those two materials were allowed to be put down a sewer and mingle with the sewage of a district they would very seriously affect the condition of the sewage. It would be quite impossible—it was quite impossible in the case I have in mind—for the local authority to control in any way the nature of the mixed sewage. At one time it would be strongly acid, and at another time it would be strongly alkaline. No man could work a sewage farm properly with variable liquid of that kind to deal with.

10251. You speak from the point of view of the sewage farm?—Oh, from the point of view of treating it. I have always contended that in tannery refuse the two liquors ought to be mixed together on the manufacturers' premises, and ought there to be allowed to subside, and the solid matters removed as far as possible before the refuse enters the sewers.

10252. You refer to cotton mill refuse. What refuse is that?—I do not know exactly what it was. I know they had a lot of it at Preston.

10253. "Cotton mills" seems to be a kind of general term?—I think it is.

10254. Because there is not found to be any refuse from cotton mills?—I really do not know what in particular it is.

10255. You express a preference for coke breeze-filters. Do you prefer them to any other kind? I have not really had enough experience of the working of different kinds to differentiate closely between them. I have seen different systems, and different ways of aerating, of blowing air in, and things of that kind, but I have not made any extended experiments.

10256. You have not a very extensive experience of artificial systems?—No, I could not say that I have an extensive experience in that respect.

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